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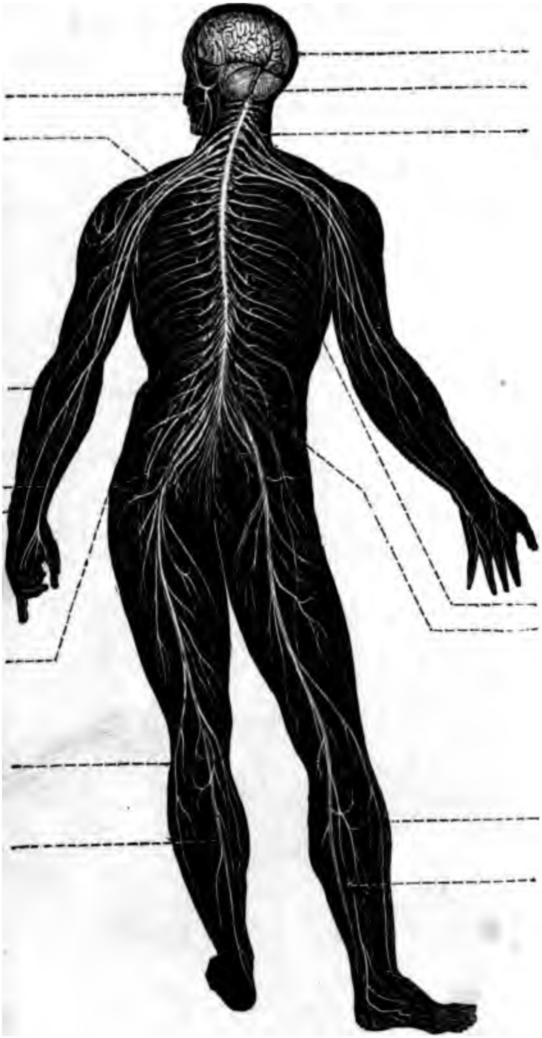

NERVOUS SYSTEM.

COMMON THINGS

EXPLAINED.

By DIONYSIUS LARDNER, D.C.L.,
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SECOND SERIES.

CONTAINING:

MAN.
THE EYE.
THE PRINTING PRESS.
THE POTTER'S ART.
LOCOMOTION AND TRANSPORT, THEIR INFLUENCE AND PROGRESS.
THE SURFACE OF THE EARTH, OR FIRST NOTIONS OF GEOGRAPHY.

FROM
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WITH ONE HUNDRED AND NINETEEN ILLUSTRATIONS.

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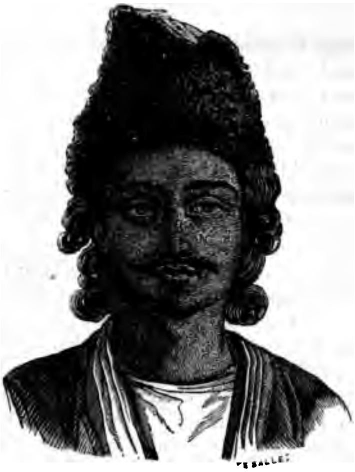

Fig. 20.—CAUCASIAN.

COMMON THINGS.

MAN.

CHAPTER I.

1. Physical condition of Man generally neglected.—2. The brain the organ of intelligence.—3. General view of the nervous system.—4. Structure of the brain.—5. The Facial Angle.—6. Its variation in different animals.—7. Recognised as an indication of intellectual power.—8. The advantages Man derives from the form of his members. —9. Prehensile and locomotive members.—10. Structure of the hand. —11. The bones of the arm and hand.—12. Wonderful play of the muscles and the movement of the fingers; example of piano-forte playing.—13. The lower members.—14. The leg and foot.—15. The erect position proper to man.—16. Man alone bimanous and bipedous.—17. Quadrumana.—18. Power of language.

1. Although it has been affirmed and quoted by generation after generation that

> "The proper study of mankind is man,"

that study, even among the most cultivated, has been confined too exclusively to the social and political condition of our race, to the total neglect of the physical relations by which it is connected with the inferior species. Although these relations exhibit in a striking point of view all that we have in common with the rest of the animal kingdom, they render manifest not less conspicuously those which set us apart from, and exalt us above them. So profoundly impressed was the greatest of modern naturalists with the force of the evidence of man's superiority, derived merely from his physical organisation, that he maintained that, even according to the rigorous principles of inductive science based on physical and mechanical phenomena, without taking into consideration the possession of the reasoning faculty, man ought to be classified, not as a species of the order of vertebrated animals, but as an order apart, distinct from and independent of all other parts of organised nature, and presenting the anomalous example of being the sole genus of his order and the sole species of his genus.*

Nevertheless, our physical organisation differs but little in appearance from that of a considerable number of Mammifers,† that is, of the animals which suckle their young. The functions of nutrition with us and with them are alike, and the structure of the organs of sense present but few distinguishing peculiarities. Yet man is placed immeasurably above all other organised beings, a superiority which he owes, not altogether to the gift of reason and of language, but also, in a great degree, to the mechanical conformation of his members.

2. Physiologists have traced a general relation between the degree of intelligence manifested by different organised beings, and the volume and structure of the brain, not only when species is compared with species, but when individual is compared with individual: and some have pretended to push this induction even so far as to connect different parts of the brain with different faculties, passions, and tendencies, founding their conclusions partly on observations of the human brain in connection with the development of human character, and partly on the analogies observable between the human brain, passions, and tendencies, compared with the brain, passions, and tendencies of inferior animals. Hence has arisen that new branch of inquiry claiming a place in physiological science under the name of Phrenology.

However questions of this order may be decided, it has never been doubted that the brain is the organ of intelligence, thought, and feeling. It is the centre of the nervous system, and is connected with all parts of the body by thousands of nervous filaments.

3. Some notion of the manner in which these diverge from the brain and from all parts of the spinal cord, and ramify over all

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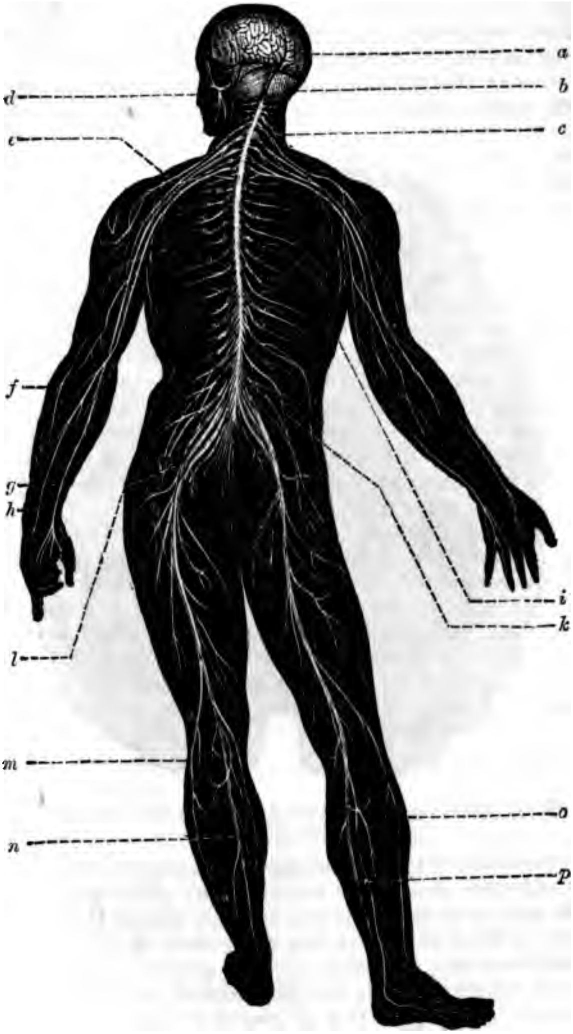
* Cuvier.

† From *mamma*, a "pap, or teat," and *fero*, "I bear."

the organs and members, may be obtained by the annexed figure, where *a* is the brain; *b*, the posterior part of that organ, called



the *cerebellum;* *c*, the spinal cord; *d*, the branch of nerves which ramifies over the face; *e*, that which goes to the arm; *f*, *g*, *h*, its ramifications over the lower arm and hand; *i*, those which spread over the trunk; *k*, *l*, those which lead to the leg and thigh; *m*, *n*, *o*, *p*, their ramifications over the leg and foot.

The innumerable nervous filaments which are thus spread over the entire system, and which at length become so minute as to be microscopic, are the messengers of thought, carrying the dictates of the will from the brain to all the members, which move in most absolute obedience to the commands thus received. They are also the conductors of sensation from all parts of the system to the brain, and are therefore divided into two classes; the first consisting of those which, carrying the dictates of the will to the movable members, are called *nerves of motion;* and the second, of those which, conveying sensation from all parts of the body to the brain, are called *nerves of sensation.* The practical proof that each of these classes of nerves is invested with the special functions here ascribed to them, is found in the fact, that if

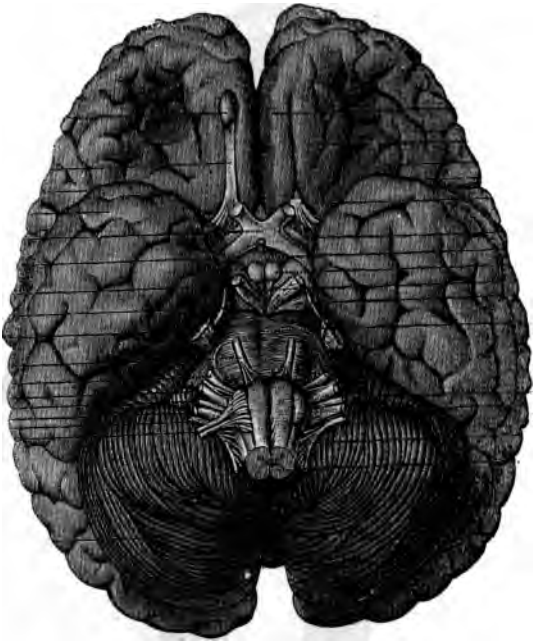


Fig. 1.—View of the inferior surface of the human brain, divested of its membranous coatings.

a nerve of motion be cut, the member which it moves will be immediately paralysed; and if a nerve of sensation be cut, the part which it connects with the brain will become insensible. Thus, for example, if the nerves of motion proceeding from the brain to the arm be divided at the shoulder, the entire arm and hand will be paralysed, the will losing all power over it. In like manner, if the nerve connecting the optical membrane of either eye be divided at any point between that membrane and the point where the nerve unites with that which proceeds from the other eye, the former eye will become blind, the sight of the latter remaining unimpaired. But if the optic nerve be divided beyond the point where the nerves from the two eyes are united, both eyes will lose the power of vision.

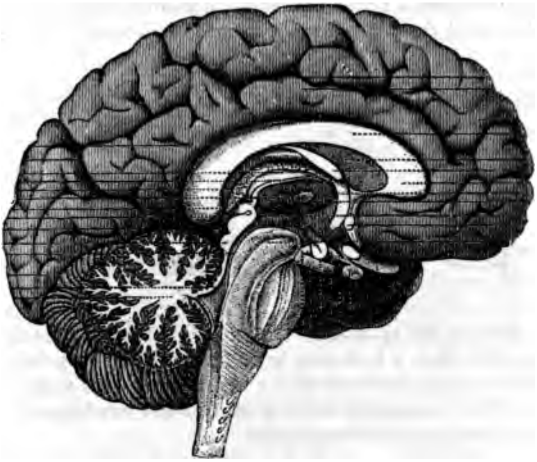


Fig. 2.—Section of the human brain, made by a vertical plane passing through the middle of the forehead.

4. The brain being the organ of intelligence, it has, as might naturally be expected, a greater development and more perfect structure in man than in the inferior animals. The *cerebral hemispheres*, as they are called, are more voluminous, and their convolutions are more prominent and numerous, and extended over a much larger region of the skull. They cover, for example, that part of the organ called the *cerebellum*, while in inferior animals they never extend over it, and in many cases have no existence at all.

The part of the brain which occupies the front of the skull in man is remarkable for the extent of its volume, and gives that peculiar elevation to the forehead and nobleness of aspect which is nowhere to be found among the inferior species.

5. The proportion which the part of the head occupied by the principal organs of sense,—those of seeing, hearing, smelling, and tasting,—bears to the part occupied by the brain and its appendages, is found to be a good general modulus of the power of the intellectual faculties; and accordingly methods have been sought by physiologists, by which this proportion can be conveniently ascertained with some degree of approximation by external indications, independently of the results of dissection. The method which has been most generally received is that proposed by Camper, an eminent Dutch naturalist, which consists in measuring what he called the *facial angle*, formed by a line, *c d*, (fig. 3) drawn through the opening of the ear and the base of the nostrils, with another line, *a b*, drawn from the most salient point of the forehead, through the front of the upper jaw. This angle will be greater or less, according to the greater or less development of the brain, especially in its anterior part.

Fig. 3.

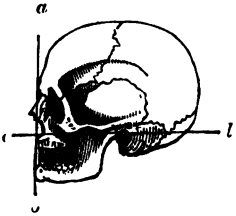
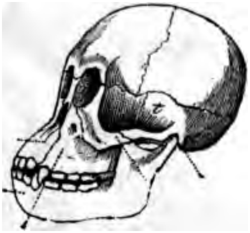


Fig. 4.



In comparing man with the inferior animals, it is found accordingly, that the facial angle exceeds those of the latter in a large proportion; and in comparing different species of animals one with another, the variation of this angle is in remarkable accordance with their several manifestations of intelligence.

6. The following are the facial angles of certain species, according to different physiological authorities:—

Man (European) (fig. 3)	85° to 90°
Ouran-Outang (fig. 4)	56° to 60°
Apes (fig. 5)	30° to 65°
Dog	35°
Ram	30°
Horse	23°

According to Professor Milne Edwards, the forehead in the case of the wild boar (fig. 6) is so falling, that it is impossible to draw a straight line from the upper jaw to the most prominent part of the skull, the latter falling considerably behind the bony projection of the nose.

Fig. 5.

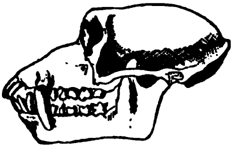
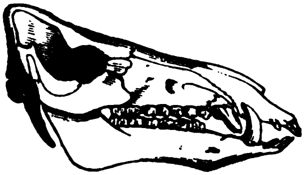


Fig. 6.

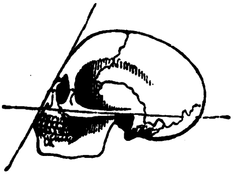


With birds and fishes the facial angle is less than with mammifers, and with reptiles, as in the crocodile (fig. 7), is often so small as to be scarcely appreciable.

Fig. 7.—Crocodile.

In comparing individuals of the human race existing in different climates and under different physical influences, the facial angle is subject to much variation. Thus, while with the European (fig. 3) it is sometimes so great as 90°, with the negro (fig. 8) it seldom exceeds 70°.

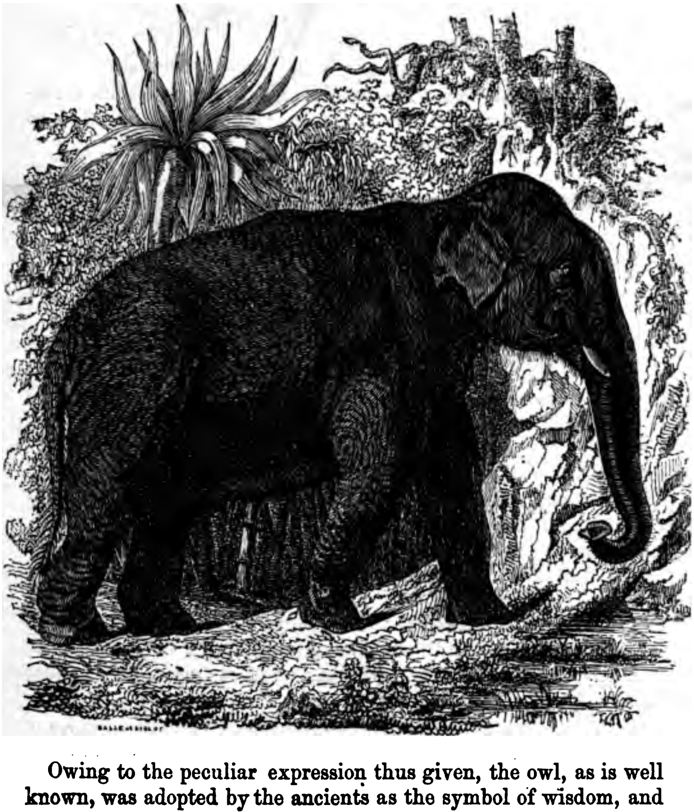
Fig. 8.



7. Although the more complete investigation of the connection of cerebral development with the extent of the intellectual faculties was reserved for modern investigators, it does not appear to have escaped the notice of the ancients, who evidently saw in the facial angle an index of intelligence. Not only do we find in their writings an erect frontal line noticed as a mark of a generous nature and an essential character of beauty, but the ancient sculptors conferred upon the figures of their heroes and their gods a facial angle much larger than is ever seen in man; and in some of the more remarkable statues which have come down to us,—the Olympian Jupiter for example,—the frontal line *b a*, fig. 3, actually inclines forwards so as to render the facial angle obtuse.

Even the most vulgar observation ascribes stupidity to a projecting mouth and nose and retiring forehead, to which the name *muzzle* is given, whether found in men or in animals. And when in exceptional cases an apparent enlargement of the facial angle is produced by a prominence of the bony arch which protects the eyes, a spurious air of intelligence is produced, which causes qualities to be ascribed to animals having this conformation, which they do not really possess. The elephant (fig. 9) and the owl (fig. 10) are examples of this.

Fig. 9.



Owing to the peculiar expression thus given, the owl, as is well known, was adopted by the ancients as the symbol of wisdom, and the Indian elephant bears an oriental name which implies the possession of a certain share of reason.

8, The brain, however, is not the only part of his organism, to which man owes his great superiority; the conformation of his members, combined with his intellectual powers, gives him a dominion over the inferior species, which he never could obtain by his natural strength or swiftness.

Fig. 10.

Like that of the superior classes of Mammifers generally, the human body is supplied with four members; the superior, or arms and hands, and the inferior, or legs and feet. It is found in the works of nature, as in those of art, that the more extensively the principle of the division of labour is carried out, the greater will be the perfection of the instruments. A tool or a machine, which attains two purposes, attains neither of them so perfectly as would two tools or machines especially adapted to the execution of each. Now we find, on comparing man with the inferior animals, that he supplies a solitary example of the rigorous application of the principle of the division of labour in the functions of his members. The necessities of its well-being require that the creature should be supplied with members to seize and members to pursue the objects of its nutrition. Hence arises the necessity for members of prehension and members of locomotion. In some of the inferior animals, as, for example, certain quadrupeds, the four members are exclusively locomotive, the act of prehension being confined to the mouth. In others, however, all the four members, besides fulfilling the functions of locomotion, are more or less prehensile, thus serving a double purpose, and therefore, according to the principle explained above, serving it by comparison less perfectly. In some, the prehensile functions of the four members prevailing over their locomotive functions, naturalists have given them the name of *quadrumana*, or four-handed, in contradistinction to that of quadrupeds, or four-footed, given to those species whose members are more exclusively locomotive.

9. In man alone are found at once members which are exclusively prehensile, and others exclusively locomotive.

10. The superior members are disposed in a manner most favourable for prehension and touch. By the peculiar mechanism of the shoulder-joint, the arm can be directed with nearly equal facility upwards, downwards, forwards, and backwards. The fore-arm at the same time being hinged upon the elbow, and the hand upon the wrist, a still more varied play is given to the hand, the immediate instrument of prehension. But even with this

variety of motion and inflection, something would still be wanting. The chief seat of the sensibility of touch is the palm of the hand and the palmar sides of the fingers; and the mechanism of the hand is so contrived as to accommodate itself to the play of this sensibility. The thumb is mounted so as to face the fingers, and the articulations of both are such as to enable them to be inflected towards each other, and towards the palm, so that when an object is embraced or grasped by the fingers, all the part of the hand possessing most sensibility of touch is brought into contact with it. If we grasp the hand of a friend or a beloved relative, the palms come into contact, and we are conscious of a mutual sensation conveyed through the nervous system. If, while the mechanism of the hand remains the same, the nerves which now overspread the palm and the palmar sides of the fingers were spread over the back of the hand, all this sensibility would cease.

It is obviously essential that the palm of the hand, which is thus its prehensive side, should be capable of being turned in all directions, so as to present itself to the objects to be grasped or touched. But the hinge joints of the wrist and elbow would only enable the palm to be inflected inwards towards the hollow of the arm.

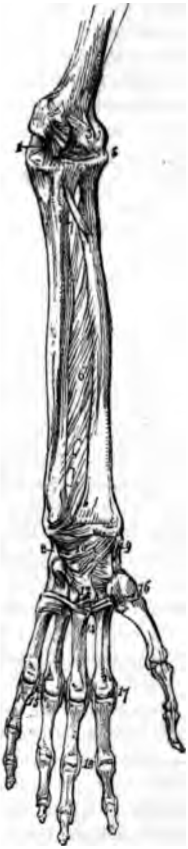
It is true that the rotatory motion which can be given to the arm upon the shoulder would vary the play of the palm, but the motion would still be imperfect for the purposes of prehension and touch. An expedient is, therefore, provided, which may be fairly said to confer upon the hand the utmost perfection as an organ of prehension. This expedient consists of a simple and beautiful mechanical arrangement in the structure of the fore arm, which is composed between the elbow and wrist, not of one, but of two bones, of nearly equal length, placed side by side. One of these, called the *ulna*, is articulated with the upper bone of the arm at the elbow by a hinge joint; the other, called the *radius*, is articulated to the hand at the wrist, with a like hinge motion. But the radius having the hand thus appended to it is so arranged that it can revolve round the ulna, carrying the hand with it, thus having the faculty of presenting the palm in any desired direction without changing the general position of the arm.

11. In fig. 11, the bones of the arm and hand are represented; the ulna, hinged upon the elbow, being on the left, and the radius, with the hand hinged upon it at the wrist, being on the right. The two bones are tied together by intermediate ligaments (6, 7), the ligament by which the hand is tied to the radius appearing at 10. The palm of the hand and the hollow of the elbow are supposed to be presented to the observer.

When to all these conditions it is added that the successive of the fingers gradually decrease in length; that they are lated with a succession of hinge joints; that they are moved endently, one of another, by a series of les acted upon by nerves which are under omplete dominion of the will, the adble perfection of the organ of prehension ouch may be in some degree appreciated.

When the movements of the arm, , and fingers, are considered collectively, y be stated, without exaggeration, that recting the fingers to any object of touch, ndred muscles are brought into opera- whose contractile power is excited by ands of nervous filaments, each of which der the absolute dominion of the will, action of volition requiring a corre- ding intellectual exertion. How wondrous machinery intellectual, physiological, and anical, must be, the least reflection upon manual exercises which are daily per- ed, especially in civilised and polished will render manifest. When a performer, xample, executes upon the piano-forte one e complicated compositions of the modern osers for that instrument, as many as ten and notes must be produced by the cation of the fingers to the keys. The st of these pieces is executed in about ninutes, or, in round numbers, 1000 ds, so that the notes must be produced e rate of 10 per second, and as each note res a separate dictate of the will, and dictate of the will a separate act of the , we arrive at the surprising conclusion these mental acts are performed in this cular case at the rate of 10 per second. can it be said that habit enables the rs to move mechanically while the mind sive, and that the facility given by repeti- upersedes mental action; for artists are found so expert as to te such pieces at sight, never having previously studied them.

Fig. 11.



The lower members are as eminently fitted for the purposes pport and locomotion as are the superior for prehension. hed to the hip bones or pelvis, at the external corners, they o articulated as to have a certain play forward, backward, and laterally, sufficient for the purpose of locomotion, yet not too great for stability.

While the arm at the shoulder plays in an extremely shallow socket, so as to give it all that vast range of motion which is necessary in an organ of prehension, but would be altogether incompatible with one of sustentation, the thigh bone is articulated at the hip in a deep spherical socket, which looks obliquely downwards, and which rests upon the convex head of the bone with sufficient firmness and solidity to afford a secure support to the incumbent weight of the trunk, the upper members, and the head.

14. The leg is articulated to the thigh at the knee by a hinge joint, which enables it to be inflected backwards, so as to accommodate itself to a progressive motion. Unlike the hand, the foot has no rotatory motion on the leg; the two bones composing which, firmly united together, confine between them the upper bone of the foot, forming the ankles at either side of it. The foot thus moves with a hinge motion on the ankle joint, projecting backwards at the heel, and still further forward in the direction of the toes, so as to supply a large basis for the support of the body.

The toes, unlike the thumb and fingers, are totally incapable of prehension; the great toe, which corresponds to the thumb, instead of facing the others, is placed in juxtaposition with them, and they cannot therefore be brought together so as to form, like the fingers and thumb, a sort of pincers.

The sole of the foot corresponds to the palm, and the instep to the back, of the hand. The bones of the latter, extending obliquely from the bend of the ankle joint to the commencement of the toes, form an elastic arch, by which the blood-vessels, nerves, and muscles of the foot are protected from the pressure of the weight of the body, which would otherwise crush them. The fleshy mass formed by the muscles and fat placed upon the sole constitutes a cushion or buffer, which softens the collision which must otherwise take place each time that the foot comes to the ground, with the whole weight of the body upon it.

15. Everything in the mechanical structure of the body conspires to prove that man was made to stand erect; and with this erect position are associated numerous consequences connected with his superiority over other species. His feet are formed with a base which is large in proportion to his body, so that the centre of gravity can be easily kept vertically over it, a condition which is essential to his stability. The legs, in their natural position, are placed at right angles to the soles of the feet, and are therefore vertical when the latter are horizontal. The centre of gravity of the trunk is at some distance in front of the spinal column, and would therefore have a tendency to incline forward, so that the

body would take the position of that of a quadruped, in which the spinal column would be horizontal, the upper part of the trunk being supported by the arms, the hands performing the duties of fore-feet. But this is prevented by the establishment along the whole extent of the back of several layers of powerful muscles, which tie the vertebræ together, two and two, three and three, four and four, and so on. The tone of these muscles is such, that their normal tension produces a force which equilibrates with the weight of the trunk acting at its centre of gravity in front of the spine. These muscles have a power of contraction and relaxation within certain limits, by which the body can be inclined backwards or forwards, more or less. The head is mounted upon the summit of the vertebral column, forming as it were its capital, in a manner obviously adapted for the vertical position. Like the trunk, its centre of gravity is a little in front of the summit to the spinal column, and therefore it would have a tendency to incline forwards, but this as before is resisted by muscles of adequate power placed on the back of the neck.

Nothing more manifestly indicates the intention of nature that man should stand erect, than the position of his face and the direction of his optic axes. In the erect position his face looks forwards, and the optic axes are horizontal. But if he were to assume the prone position, supported by his four members like a quadruped, the optic axes would be directed downwards, and, except by a strained effort of the neck, he could not see before him. To this it may be added, that the knee joint being so constructed that the leg can only be deflected backwards on the thigh, would render the legs utterly unfitted to be members of support and locomotion in the prone position, since in that case the point of support would be, not the feet, but the knees. Now, independently of the consideration that in this case the legs and feet would not only become useless, but would be an impediment to every act of locomotion, the shortness of the thigh would inconveniently limit the power of progression, the thin integuments covering the knee-pan would soon be destroyed by the pressure upon it, and the knee-pan itself, a loose and detached bone, would be displaced, and the members totally disabled.

It would not be worth while to insist upon these particulars, were it not that some authors, impelled doubtless by the love of paradox, have maintained that the prone position is natural to man, and the erect position the result of education.

16. Man, then, alone presents the characters of a *bimanous* and *bipedous* animal. The various species of apes, who approach so close to him in some respects, differ from him essentially in their members, their inferior or posterior members having as much the

character of hands as of feet, and their anterior members as much the character of feet as of hands.

In fig. 12 is represented the species of ape called the chimpanzee, using the anterior member as a prehensile organ. In fig. 13 another species of quadrumana is shown, where the conformation of all the four feet closely corresponds with that of the human hand, but all the four are used for support and locomotion.

It is evident that the mode of locomotion to which the mixed character of the hand and foot found in the quadrumana is best adapted, is that of climbing, to which accordingly the monkey tribes are more especially addicted, often carrying their young clinging round their bodies as they mount.

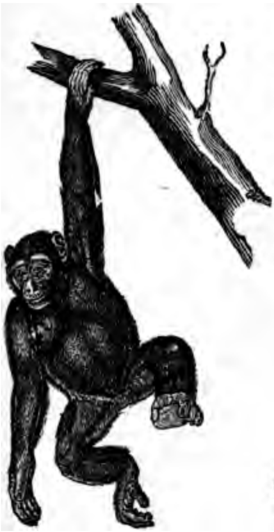


Fig. 12.—The Chimpanzee.

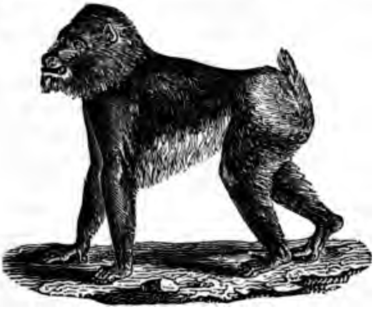


Fig. 13.—The Mandrill.

In fig. 14, a monkey called the *maki*, a species of lemur, is represented in one of its habitual attitudes, carrying its young.

17. The double purpose of prehension and locomotion assigned to the members of the quadrumana, and their habitual exercise of climbing in pursuit of their food and for protection from their enemies, renders the occasional aid of another organ of prehension necessary; such an organ is accordingly supplied them in the tail. In fig. 15 is represented the White-throated Monkey thus exercising this prehensile action. The same action is common with the species called the *Coaita*, or Spider-Monkey, so named from the extraordinary length of its extremities, and from its motions. "The tail," says Sir Charles Bell, "answers all the purposes of a hand, and the animal throws itself about from branch to branch, sometimes swinging by the foot, sometimes by the fore extremity,

but oftener and with greater reach by the tail. The prehensile part of the tail is covered with skin only, forming an organ of touch as discriminating as the proper extremities. The *Caraya*, or Black Howling Monkey of Cumana, when shot, is found suspended by its tail round a branch. Naturalists have been so struck with this property of the tail of the *Ateles*, that they have compared it to the proboscis of the Elephant, and have assured us that they fish with their tail.

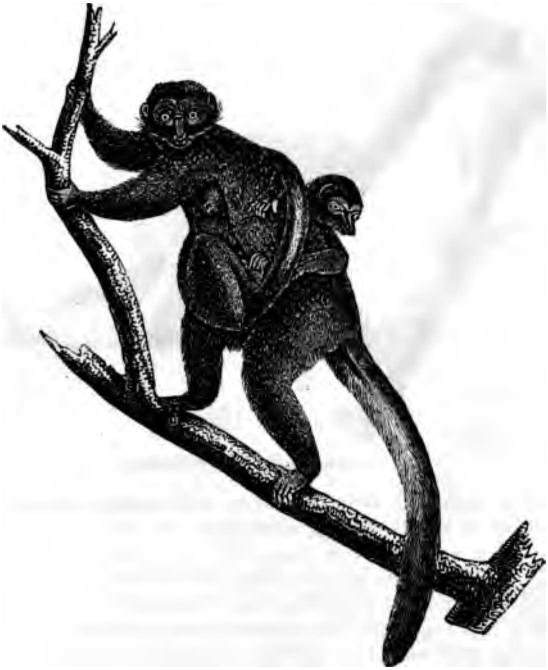


Fig. 14.—The Maki.

"The most interesting use of the tail is seen in the opossum. The young of that animal mount upon her back, and entwine their tails round their mother's tail, by which they sit secure while she escapes from her enemies." *

It will be observed that the young one, represented in fig. 14, also uses its tail as an organ of prehension, holding itself upon the body of its mother by twining the tail round her.

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* Bell, On the Hand, p. 20.

18. But of all the organs to which man owes his superiority, that of voice is incontestably the most important. He alone, among all created beings, is endowed with the power of producing articulate sounds in infinite variety, and applying them to the expression of his thoughts, sentiments, and feelings. By this power he is enabled to communicate with his kind, to interchange with them the expressions of kindness and affection, and to impart and receive knowledge and information. Great as this power is, it is augmented in a manifold proportion by the device of expressing oral sounds by written or printed characters. By this expedient oral language becomes visible, and is, so to speak, perpetuated; the discourse which is spoken or listened to, however impressive may be the eloquence of the speaker, and however profound the attention of the hearer, may, and generally does, soon fade from the memory, but language printed or written is permanent,

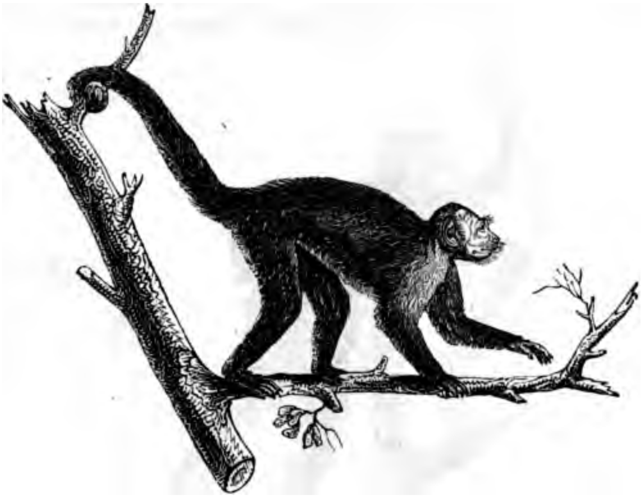


Fig. 15.—The White-Throated Monkey.

Litera scripta manet,

and may be referred to again and again until the reader renders it his own.

The printed book can be handed down and reproduced indefinitely from age to age, and those of one generation are thus enabled to listen to the precepts and imbibe the counsels of the wisest and most virtuous of former times.

Fig. 21.—MONGOL.

COMMON THINGS.

MAN.

CHAPTER II.

19. Physical feebleness of man.—20. His helpless infancy.—21. His great power nevertheless.—22. Man gregarious.—23. His dentile apparatus.—24. Why nevertheless he uses animal food.—25. His migratory power and distribution over the globe.—26. View of his progress from the cradle to the grave.—27. Births.—28. Cases of two and three at a birth.—29. Births more prevalent at certain seasons.—30. Proportion of the sexes born.—31. Proportion in the case of illegitimates.—32. Chances of life more favourable for females.—33. Organs of sense in infancy—the eye.—34. The voice.—35. The bones.—36. Instinct in the infant.—37. Terror of falling.—38. Milk teeth.—39. Permanent teeth.—40. Their periods of emergence.—41. The average height of men.—42. Giants and dwarfs.—43. Average height of women.—44. The influence of race.—45. Influence of climate.—46. Hygienic conditions.—47. Their effects shown by conscription in France.—48. Rate of growth from infancy to maturity.—49. Progressive increase of bulk. —50. Organic changes at puberty.—51. Organic changes in the bones. 52. The muscles.—53. Examples of longevity.—54. Great mortality in infancy.

19. MAN thus singularly favoured by the possession of reason, and by the address and precision of which the motions of his

members, and more especially those of the hand, are susceptible, is, nevertheless, in some of his physical attributes, immeasurably inferior to other animals which correspond with him nearly in size. He is neither swift of foot to pursue his prey or fly from his enemies; nor is he supplied with any natural weapons of attack or defence, such as those which are found among the numerous classes of animals around him. He is not only feeble and defenceless, but Nature has refused to provide him with those means of protection from the inclemency of the elements, which she has so beneficently supplied to those who hold a lower place in the chain of organised beings. He has neither the fur of the beast, nor the feathers of the bird, to protect him from the rigours of temperature, and yet his body is covered with a skin and integuments abounding in nerves, which render it ten thousand times more sensitive than the skin of any of these creatures which Nature has so carefully and tenderly protected.

20. In coming into the world, he is more helpless and delicate than the young of any other creature, and continues for a much longer period dependent, not for his well-being only, but for his very existence, upon the assiduous and never-ceasing solicitude and tenderness of his parents.

21. Yet this creature, thus naturally poor, feeble, naked, helpless, and defenceless, is the lord and master of the material world. By him the strongest is subdued, the fiercest tamed, the swiftest overtaken. He cannot rise into the air, nevertheless he arrests its inhabitants in their flight and brings them to his feet. He cannot descend into the waters, nevertheless he calls forth from the chambers of the deep their tenants, for the supply of his wants and the gratification of his appetites. His body is unprotected by any natural covering, but the beasts of the forest and the birds of the air are compelled to surrender for his use their fur, and their plumage. Innumerable textile plants, which in their natural state would be unavailing, are adapted by his art to supply the materials by which clothing for his body can be made in unbounded quantity. Unable to endure the vicissitudes of temperature and climate, the earth itself is compelled to surrender its bowels, and to supply inexhaustible quantities of fuel, by which artificial heat is produced to moderate the rigours of cold and equalise temperature. He is not swift of foot to pursue or to fly, but he tames for his use the swiftest of subordinate creatures, which with the most absolute obedience transport him where he wills. Not satisfied even with this, his inventive powers have created engines of transport which carry him over the face of the waters, in spite of opposing wind and tide, and over the surface of the land, with a speed which

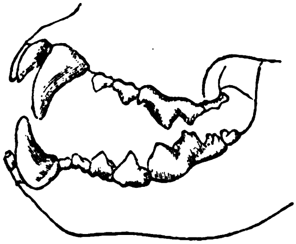
exceeds the flight of the swiftest bird and equals the rapidity of the tempest.

So far, then, from having reason to repine at his helpless and defenceless organisation, he is indebted to those apparent defects for the greatest of his attainments; for it is certain, that if he had possessed natural organs of defence, attack, and locomotion, and natural protection for his body at all analogous to those which have been provided so generally for the inferior species, he would have lost that strong stimulus which has urged him on to such stupendous and almost incredible achievements. Nor is this observation novel. At a much earlier epoch in the progress of the human race, and ages before the great discoveries had been made which will render for ever memorable the last hundred years, Galen observed, that if man had possessed the natural clothing and defence of the brute, he would never have been an artificer, nor protected himself with a cuirass, nor fabricated the sword or spear, nor invented the bridle, nor mounted a horse, nor hunted the beast. Neither would he have followed the arts of peace, nor constructed the pipe and the lyre, nor erected houses or palaces, nor temples to the gods; nor would he have made laws, nor invented letters by which he would hold communion with the wise of antiquity, conversing at one time with Plato, at another with Aristotle, and at another with Hippocrates.

22. The possession of the faculty of language necessarily infers the instinct of sociability, and man cannot live alone. He seeks the society of his kind, and belongs to the class which naturalists call *gregarious*. The advantages derived from this habit of association are infinite; without it, indeed, man, instead of being as he is, the monarch of nature, would be amongst the most miserable of animals, and would assuredly soon disappear from the earth. But by association every individual strengthens and supports others, and is strengthened and supported by them. Each cultivating some special faculty or power in a higher degree than his fellows, renders it serviceable to them, and receives in return equivalent services from those who have cultivated other powers in which he is deficient; and thus comes into play that vast principle of material production and social felicity known as the division of labour.

Like all other gregarious animals, man is naturally frugivorous, or made to live on fruit and vegetables. This is a conclusion not resting solely upon the analogy observable between man and other gregarious species, but supported by the characters of his organs of nutrition. The teeth of carnivorous species (fig. 16) are peculiarly formed for tearing and masticating the flesh which constitutes their proper food. The canine teeth are largely developed, sharp and curved; and the incisors partake of the canine character. The teeth which occupy the place of molars, edged and sharp, close side by side like the blades of scissors. The dentile apparatus is thus adapted to tear and cut the flesh before it passes into the stomach. The teeth, on the contrary, of frugivorous animals consist of incisors and molars; the canine teeth existing, but so little developed as to have no functions different from those of incisors. The molars of the two jaws, nearly flat at their ends, come into direct contact and superposition like two millstones, and the jaws, by a small lateral motion, have the power not only of bruising but of grinding the food between them. These operations are all that is necessary and sufficient for vegetable, but would be altogether inapplicable to animal food.

Fig. 16.



23. Every one will recognise in the dentile apparatus last described the form and structure of the human teeth; and so far as they are an index of the food adapted to them, it is plain that man is frugivorous. But the same conclusion is further supported by an examination of the digestive apparatus.

In carnivorous species, the intestine through which the food passes is generally short, its length not exceeding three or four times that of the body, while in the herbivorous species it is usually ten or twelve, and sometimes (as in the sheep, for example) twenty-eight times the length of the body. In accordance with this principle, we find that the human intestine, like the teeth, is suited to vegetable aliment, having a length bearing a proportion to that of the body, which is analogous to the internal structure of other frugivorous species.

24. How then, it may be asked, has it happened that man, instead of being exclusively frugivorous, is, in fact, omnivorous, nourishing himself indifferently with vegetable and animal aliment? The answer is obviously, that he cannot be nourished by animal aliment, unless it be previously prepared by fire. In a word, flesh, to be fit for human food, must be cooked.

25. One of the physical peculiarities which distinguishes man from other members of the animal kingdom, is the facility with which his organisation adapts itself to differences of climate, and this is one of the marks which appear to confirm his destiny to rule over the whole surface of the globe. Placed originally by his Maker in a single region, his race has multiplied and diffused

itself, manifesting a constant tendency to emigration, and being deterred neither by the rigours of the pole, nor the scorching sun of the tropics, it has overspread the globe. According to statistical estimates, which are considered as exact as such calculations can be, it was ascertained that, at the epoch of 1840, the total population of the globe amounted to about 737,000000, which were distributed in the following proportions, the number to every square league, taking the length of a league as the 25th part of a degree, being given in the second column :—

	Population.	Per Sq. League.
Europe	227,700000	472
Asia	390,000000	184
Africa	60,000000	40
America	39,000000	20
Oceania, including the isles of the Pacific Ocean, &c.	20,000000	37

The density of the population, indicated in the last column, depends more on civilisation and wealth than on climate. Thus, it is computed that the number of inhabitants per square league in the different states of Europe, are as follows :—

United Kingdom	1480
France	1200
Prussia	895
Russia	202

26. Having taken this rapid view of the physical organisation and condition of the human race, let us trace the progress of the animal Man from the cradle to the grave.

27. In general, man comes into the world singly, or one at a birth. In certain exceptional cases, two are born, and called twins. The cases in which three or more at a birth are produced are so extremely rare as not to have received in any language, that we are aware of, a distinct appellation.

28. It appears by statistical returns, that, upon an average, one case of twins occurs in 90 births; and that three at a birth has occurred only once in 30000 cases.

29. Another circumstance, in which the human race is distinguished from inferior animals, is the independence of the phenomenon of birth on the season of the year. Animals generally produce their young at that season which is most favourable for their development. Children are born at all seasons. Nevertheless, in comparing the number of births with the course of the

seasons, it is found to be variable, and that its variation has a marked and well-ascertained relation to the course of the seasons. It is found generally in the temperate climates, that births are more numerous in the three winter, and least so in the three summer months. In approaching the colder climates, the epochs of the maximum and minimum numbers are later, and in approaching the warmer climates earlier.

30. The number of children which come into the world is not equally shared between the sexes, the male always predominating.

This fact has been established in all countries where statistical registers have been kept; and it is remarkable, that although the numerical proportion between the sexes is subject to some variation from year to year, its mean amount in each country is nearly invariable, though different in one country as compared with another. Thus, on comparing the numbers of male and female children baptised in England and Wales during the first half of the present century, it is found that the number of males invariably exceeded the number of females in a proportion, varying from year to year, from 25 to 50 per 1000; the mean result taken for the whole period showing, that for every thousand girls born, there were one thousand and forty boys.

In France, according to returns extended over 36 years, terminating in 1852, it appears, that for every thousand girls there were one thousand and sixty-one boys born. Thus the preponderance of male births in France exceeds that in England in the proportion of a little more than 6 to 4.

By returns obtained from other countries where accurate statistics are kept, it has been found that the preponderance of male births is intermediate between those of England and France, the number of males being 1050 for every 1000 females.

31. A very remarkable fact, indicating some undiscovered physiological law, has been developed by the analysis of the returns of the registrations of births obtained from France and other countries where the most exact statistical records are kept. It has been found generally, that in that particular class of children, to which foundlings for the most part belong, the preponderance of male births is considerably less than in the case of marriage-born children. Such a circumstance would naturally enough be regarded as merely accidental, if it were not found to prevail invariably, at all epochs in all countries where registers are kept with sufficient precision to test the fact, and in all provinces of the same country. Thus, for example, while in France there are 1060 marriage-born boys for 1000 girls, there are only 1040 boys of the other class for the same number of girls; and

this proportion has been found to be maintained from year to year, and equally in different departments.

From a comparison of the births in different departments of France, north and south, it has been found that the proportion of the sexes born is not affected by climate.

32. It must not be supposed, however, that this ratio between the sexes continues through life. The chances of life being more favourable on the whole to females than to males, the excess given to the latter at birth is equalised before the middle age; and at more advanced ages, the balance turns the other way, and the females predominate.

33. In coming into the world, the infant can open the eyes, but physiologists consider that it has no sense of vision, and that it is only at the end of some weeks that it begins to be sensible of visible objects. After this, it directs its looks to objects which are most brilliantly illuminated, or which are characterised by the most vivid colours. It then, by slow degrees, begins to distinguish objects around it, but it has been ascertained that a considerable time elapses before it has any idea of distances or magnitudes.

Indeed, this is quite consistent with effects which have been found to result from surgical operations in which sight has been restored to persons blind from infancy. In such cases, it has been stated that the subject of the operation, when first enabled to see, imagined that all the objects which he beheld were in immediate contact with his eyes, and had not the least idea of their relative distances, nor any other notions of their magnitudes or forms than such as were afforded by their profiles. Every object, in short, appeared as a coloured silhouette in close contiguity with the organs of vision.

34. The other organs equally undergo a progressive improvement by exercise. During five or six months the infant makes no other vocal sound than inarticulate cries. It begins gradually to be sensible of pleasurable emotions from the contemplation of external objects, which are expressed by its smiles. The cries gradually assume the tone and character of the voice, and are accompanied by incipient efforts at articulation, and towards the close of the first year the more simple monosyllabic words are pronounced.

35. The bones, which at the time of birth consist to a great extent of cartilage or gristle, and have no strength sufficient to support the body, receive, in the process of nutrition, a gradual accession of the earthy constituent called the phosphate of lime, which gives them hardness. Contemporaneously with this increase of strength in the bones, there is a proportionate growth

and increase of strength in the muscles which move them, and about the close of the first year this strength bears such a relation to the weight of the body, that the child is enabled to support itself on its legs, and by gradual practice acquires the ability to walk.

36. It is generally assumed that man is distinguished from the inferior animals by the substitution of reason for instinct, and in this way it is explained how the young of other animals manifest at the moment of birth the possession of powers and faculties, which, in the case of the young of the human race, are acquired only by long practice and slow degrees. It is therefore contended, that while the young of the lower animals are governed exclusively by instinct, the young of man is as exclusively governed by reason, the conclusions of which are based upon experience. The acts prompted by instinct are performed as perfectly at first as at last, and undergo no progressive improvement; while, on the contrary, the dictates of reason being based upon experience, cannot be issued by the mind until the results of that experience, which are their only data, have been developed. It has, therefore, been argued, that the helplessness of the infant, and the slow and gradual progress of the exercise of its senses and members, must be explained by the total absence of instinct. This conclusion, however, it seems cannot be admitted in its absolute sense, and observation and experience show that it requires considerable qualification. Many eminent physiologists impugn it, and Sir Charles Bell has even expressed a doubt whether the actions of the body, if not first instinctive or prompted by innate sensibilities, would ever be exercised under the exclusive influence of reason. The sensibilities and motions of the lips and tongue are, according to him, perfect at birth; and the fear of falling is manifested by the infant long before the results of experience can suggest it. The hand, destined to become the instrument not only for the improvement of the senses, but for the development of the mental faculties, is absolutely powerless in the infant. Although capable of expressing pain, it is unconscious of the part injured. But the lips and tongue immediately betray their sensibility. Later, the infant puts its fingers into its mouth to suck them, and so soon as they are capable of grasping, whatever they lay hold of is carried to the mouth.

"The first office of the hand, then, is to exercise the sensibility of the mouth, and the infant as certainly questions the reality of things by that test, as does the dog by its acute sense of smelling. In the infant the sense of the lips and tongue is resigned in favour of that of vision, only when the exercise of the eye has improved and offers greater attraction. The hand acquires the sense of touch very slowly, and many ineffectual efforts may be observed in the arms and fingers of the child, before it can estimate the direction or distance of objects. Gradually the length of the arm, and the extent of its motions, become the measure of distance, of form, of relation, and perhaps of time.

37. "Next in importance to the sensibility of the mouth, we may consider that sense which is early exhibited in the infant, the terror of falling.

"The nurse will tell us that the infant lies composed in her arms, while she carries it upstairs, but that it is agitated when she carries it down. If an infant be laid upon the arms and dandled up and down, its body and limbs will be at rest when it is raised, but in descending it will struggle and make efforts. Here is the indication of a sense, an innate feeling of danger, and we may perceive its influence when the child first attempts to stand or run. When set upon its feet, the nurse's arms forming a hoop around it, without touching it, the child slowly learns to balance itself and stand; but under a considerable apprehension. It will only try to stand at such a distance from the nurse's knee, that if it should fall, it can throw itself for protection into her lap. In these, its first attempts to use its muscular frame, it is directed by a fear which cannot as yet be attributed to experience. By degrees it acquires the knowledge of the measure of its arm, the relative distance to which it can reach, and the power of its muscles. Children are, therefore, cowardly by instinct; they show an apprehension of falling, and we may trace the gradual efforts which they make under the guidance of this sense of danger to perfect the muscular sense. We thus perceive how instinct and reason are combined in early infancy; how necessary the first is to existence; how it soon becomes subservient to reason, and how it eventually yields to the progress of reason, until obscured so much that we can hardly discern its influence." *

38. At the moment of birth, twenty teeth already formed and ossified are deposited, ten in the lower and ten in the upper jaw, but are completely covered by the gums. The mouth is thus constituted exclusively for application to the mother's breast and for the suction of milk from it, and the stomach and intestines are organised in accordance with this for the due digestion of that aliment. The constituents of the healthy milk of woman are the same as those of the body of the child, and enter into its composition in a corresponding proportion. By the process of digestion, they are distributed among the several organs of the child's body,

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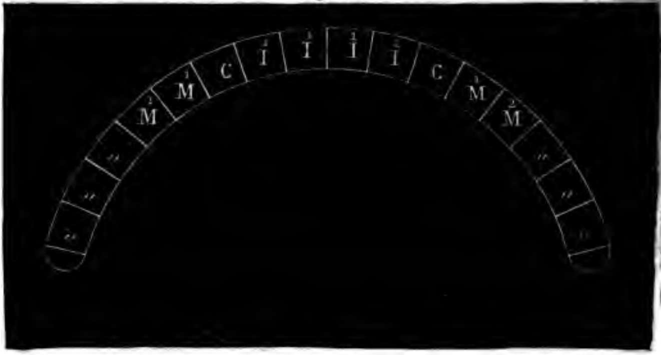
* Bell, On the Hand, p. 233.

each passing to that for whose sustenance and growth it is fitted. At the age of from six to ten months, the first teeth penetrate through the gum, and towards the end of the second year the entire number have appeared. These twenty teeth are classified according to their peculiar forms, as incisors, canines, and molars. The incisors are chiselled, the canines pointed, and the molars presenting a broad and rough summit. When the mouth is closed the molars of the upper jaw corresponding in position with those of the lower, rest upon them. But the lower incisors and canines lie within the edges of the upper ones. In each of the jaws, there is, however, space for sixteen teeth, and consequently three places at each side remain unoccupied.

The relative arrangement of this set of teeth is shown in fig. 17, where the incisors are indicated by I; the canines by C, and the molars by M; the unoccupied spaces being marked "

The first teeth which break through the jaw, are the middle incisors I^1 I^1; these are succeeded in regular succession by the lateral incisors I^2 I^2, the canines C C, and the molars M^1 M^1 and M^2 M^2.

Fig. 17.

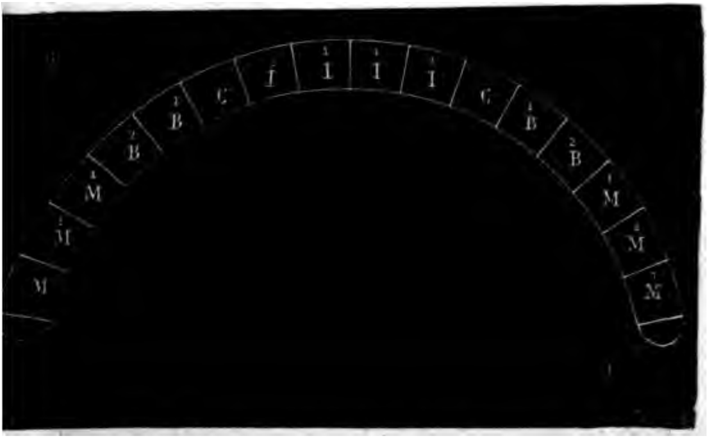


39. This first set of teeth are called the milk teeth, because of their emergence from the gums at the time when the aliment of the child is changed from the milk of the mother to other forms of food. Towards the seventh year, these teeth begin to be pushed out of the jaw by another set which have been growing beneath them. The incisors and canines are pushed out by another set perfectly similar in form and name, which take their places. The molars are in like manner extruded by four teeth in each jaw called *bicuspids*, having an intermediate character between incisors and molars.

Later still, four molars issue from the gum in each jaw, two at each side, occupying the first two of the three vacant places marked " in fig. 17, and at a still more advanced age, two other molars issue from each jaw, filling the last vacant place marked " in the fig. 17.

Thus, a set of sixteen permanent teeth is established in each jaw (fig. 18). The last four molars, which emerge at a period of life much later than the others, have been for that reason vulgarly called wisdom teeth.

Fig. 18.



40. The periods of the successive emergence of the permanent teeth are, according to Cartwright, as follows:—

	AGE.
Middle incisors of lower jaw (I^1), and first molars (M^1)	5 to 7
Middle incisors of upper jaw	6 to 8
Lateral incisors (I^2)	7 to 9
First bicuspids (B^1)	8 to 10
Canines (C)	9 to 12
Second bicuspids (B^2)	10 to 12
Second molars (M^2)	12 to 14
Third molars (M^3) (wisdom teeth) . . .	17 to 25

41. The mean height of man is about 5 feet 6 inches, but is subject to great variation, not only in the case of individual compared with individual, but nation with nation, and race with race. Some of the savage tribes of Patagonia, and the inhabitants of the Navigator and Caribbean islands, are remarkable for their elevated stature, their average height varying from 6 feet to 6 feet 3 inches.

On the contrary, the Esquimaux and Bushmen have an average height not exceeding 4 feet 3 inches.

42. If, instead of comparing people with people, individual be compared with individual, still greater departures from the average standard are found. Thus, we have seen giants which have attained the enormous height of 9 feet 6 inches, and, on the other hand, dwarfs whose height did not exceed 2 feet.

43. Among persons of average height, women are about a sixteenth less tall than men; but among people whose average height is less than the common standard, such as the Esquimaux and Bushmen, there is less inequality between the sexes; while in those of greater average height, such as the Patagonians, the inequality is greater. In fact the sexual inequality appears to vary nearly in the ratio of the mean stature.

The inequalities of mean stature observed in comparing people with people, depend partly upon race, or partly on the physical conditions with which they are surrounded.

44. The influence of race is more especially apparent when different people, inhabiting the same country, with similar manners, and subject to like climatological influences, are compared together. In Patagonia, for example, where certain nomadic tribes of very elevated stature prevail, there are others whose stature has about the ordinary standard, and at a little distance in the Tierra del Fuego, people of low stature prevail. The people of greatest mean stature are found chiefly in the southern hemisphere, either on the South American continent, or in the several archipelagos of the Southern Ocean.

45. Although people of low average stature are found within the tropics, and in places near the Cape of Good Hope, where the climate is sufficiently temperate, it cannot be doubted that a rigorous climate is unfavourable to the development of the human form, for in high latitudes in both hemispheres the inhabitants are invariably characterised by diminutive stature.

Moderate cold, on the contrary, is favourable to the corporeal development. In France and other parts of Europe, where the climate is mild, the average stature is less than in the colder parts of Europe, such as Sweden, Finland, and even Saxony and the Ukraine.

46. Temperature, however, exercises on the whole less influence upon bodily development than the general hygienic conditions of a people, and it may be received as a general principle that the mean stature will be so much the more elevated, and the complete growth sooner accomplished, other things being the same, as the country inhabited by a people is more fertile and abundant, and the sufferings and privations sustained during youth less consider-

able. Innumerable proofs of this truth may be found by comparing nation with nation. But it may be rendered still more strikingly apparent by comparing together the inhabitants of different provinces of the same country, or even those of different divisions of a large city.

47. It is well known that, by the laws of France, the army is recruited by conscription, in carrying out which means are incidentally supplied of ascertaining with great precision the sanitary condition and bodily development of the population. The capital of that country, containing upwards of a million of inhabitants, is distributed into quarters, called arrondissements, which differ one from another in relation to wealth or poverty, even more than do the various quarters of London. Thus while in the north-western arrondissements misery and want are rare, in some others, such as the 6th, the 11th, and the 12th, they prevail to a great extent. In the former, 45 in every 100 conscripts are found unfit for military service, chiefly because of insufficient stature, and the remaining 55 have an average height 5 feet 6½ inches, while in the latter quarters, where poverty is more prevalent, 52 in a 100 are rejected, and the remaining 48 have an average height of only 5 feet 6 inches.

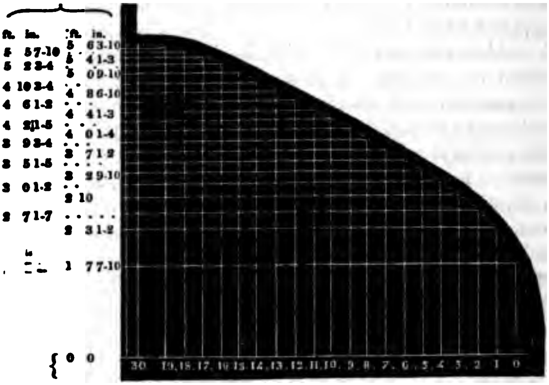
48. Statistical returns sufficiently exact and regular to indicate the average progressive growth of the human body, though rare, are not unattainable. In Belgium, for example, where the average stature is somewhat greater than in France, it has been found that the average height of new-born infants is 19⅓ inches, and at the end of the first year it is increased to 27½ inches.

In the second year the growth is less rapid, and in every succeeding year becomes less and less so, until the full growth has been attained. The annexed diagram, however, fig. 19, will convey a more exact notion of the mean progressive growth than could any mere numerical statements. It is due to M. Quetelet, to whose physical and statistical researches science is otherwise so largely indebted. The successive years in the age of an individual, from the moment of birth to the age of thirty, are indicated in the horizontal line, and the corresponding average heights in the vertical column.

It appears, therefore, that at the moment of birth the infant has a stature equal to about 2-7ths, and at three years old, about half of its ultimate height.

At the moment of birth, the average height of boys exceeds that of girls by about the 20th of an inch, and this difference increases with their growth. Nevertheless, the results obtained by M. Quetelet must be received merely as first approximations; the observations and inductions necessary to establish general and certain laws being much more numerous than any which statistical records have yet supplied. It may, however, be assumed that in extreme climates, whether hot or cold, the body arrives at its full height sooner than in temperate climates; in towns sooner than in the country, and in plains sooner than in mountainous districts.

Fig 10.



49. The development of the body in bulk is slower than its growth in height. A new-born infant has upon an average about a twentieth of the weight which it will acquire upon attaining its greatest development, which takes place in general for men at 40 and for women at 50.

During the first year after birth, the increment of weight is about $\frac{1}{10}$ of all that it will receive during its subsequent existence; and the increase of weight received from the 15th to the 20th year is even greater than that which is acquired in the first five years.

50. On arriving nearly at the limit of his stature, the male passing from youth to manhood undergoes several organic changes. His bones having acquired a larger proportion of the earthy constituent, have increased strength, his muscles are more developed and powerful. His voice losing the feminine pitch which characterises boyhood, becomes almost suddenly much more grave, and his beard is rapidly developed.

The corresponding changes in the female organism are manifested somewhat earlier, and show themselves by external forms familiar to every eye. The chest becomes enlarged, the shoulders expanded, and the pelvis acquires greater width, and the forms of womanhood become conspicuously visible. In temperate climates these changes are manifested at from 14 to 16 years of age. In warm climates they take place at from 10 to 11, and in colder countries are postponed to 17 or 18.

EFFECTS OF GROWTH.

51. Growth produces in the species a somewhat remarkable change in the mechanical qualities of the bones. This important part of our organism consists of three constituents, fibre, cartilage, and the earthy matter already mentioned called *phosphate of lime*. From the fibre they derive their toughness; from the cartilage their elasticity, and from the lime their hardness and firmness. Nothing can be more admirable in the economy of our body than the manner in which the proportion of these constituents adapts itself to the habitudes of age. The helpless infant, exposed by a thousand incidents to external shocks, has bones, the chief constituents of which being gristly and cartilaginous, are yielding and elastic, and incur little danger of fracture. Those of the youth, whose augmented weight and increased activity demand greater strength, have a larger proportion of the calcareous and fibrous elements, but still enough of the cartilaginous to confer upon the solid framework of his body the greatest firmness, toughness, and elasticity. As age advances, prudence and tranquil habits increasing, as well as the weight which the bones have to sustain, the proportion of the calcareous constituent increases, giving the requisite hardness and strength, but diminishing the toughness and elasticity.

While the bones thus change their mechanical qualities as age advances, they diminish in number, the frame consequently having fewer joints and less flexibility. The bones of a child, whose habits require greater bodily pliability, are more numerous than those of an adult, several of the articulations becoming ossified between infancy and maturity. In like manner, the bones at maturity are more numerous than in advanced age, the same progressive ossification of the joints being continued.

It has been ascertained by anatomists that, on attaining the adult state, the number of bones constituting the framework of the human body is 198; of which 52 belong to the trunk, 22 to the head, 64 to the arms, and 60 to the legs.

52. This wonderful solid structure is moved by a mechanical apparatus, consisting of about 400 muscles, each of which is attached at its extremities to two points of the body, more or less distant from each other, which it has the power of drawing towards each other by a contractile property peculiar to it. These muscles, however, being passive pieces of mechanism, are moved as already mentioned by the nerves, while the nerves themselves are moved by the will, and here the material mechanism ends, and the intellectual or the spiritual begins.

As age advances, the organs lose their suppleness and elasticity; the weight of the body undergoes a sensible diminution; the powers of digestion and assimilation are gradually impaired; the vital flame decreases in splendour, and flickering in its socket, at length, and with apparent reluctance, goes out.

53. Death, however, by the mere effect of age, is extremely rare, being in most cases produced by accidental causes, to which imprudence exposes us. Innumerable examples prove to how great an extent life may be prolonged beyond its average limits. Without citing the extraordinary examples of longevity found in the records of the first ages of the world, supplied by the Sacred Scriptures, examples sufficiently numerous may be produced nearly from our own times.

One of the most remarkable examples of longevity which modern times have presented, is that of a poor fisherman, an inhabitant of Yorkshire, by name Henry Jenkins, who died in 1670, at the age of 157. Peculiar circumstances have incidentally supplied evidence of the great ages of this individual, and two of his sons. He was summoned on a certain occasion before a court of justice, to give evidence of a fact which had occurred 140 years previously; and he appeared before the tribunal attended by his two sons, the younger of whom had attained the age of 100, and the elder that of 102. Various other examples are cited of nearly equal longevity, but for the most part they refer to times or places at which the registers of births and deaths were not kept with such regularity as to entitle the statement to confidence. It is, however, extremely rare to find an individual who has exceeded the age of 100. According to the bills of mortality of the City of London, it appears that, of 47000 deaths which took place in the ten years ending in 1762, there were only 15 centenarians. In France, during the three years ending with 1840, there were 2,434993 deaths, of which 439 were reputed centenarians, which would give a proportion of about 1 in 5500.

54. One of the saddest spectacles presented by the analysis of the general progress and termination of human life, is the vast proportion of our race which are swept away in the first years of their existence; a circumstance which can only be explained by the care which infancy requires, and the inability of the poor and labouring classes to bestow it. It appears, from the statistical records so accurately kept in France, that of every 100 children born, 24 die in the first year; 33 in the first two years; 40 in the first four years; and 50 in the first twenty years. Thus it appears that only half the children born in France survive for the purpose of the continuance of the race. According to similar records published in England, it appears that 40 in 100 die in the first 5 years, and 11 more between that and 20; so that the survivors at 20 are something less than half the number born.

Fig. 22.—ETHIOPIAN.

COMMON THINGS.

MAN.

CHAPTER III.

55. Average duration of life.—56. In England and France.—57. Great mortality of foundlings.—58. Average number of children per marriage.—59. Influences which produce permanent changes in man.—60. Indications of a common origin for the human race.—61. Naturalists in this verify the Hebrew Scriptures.—62. The five races of men.—63. The Caucasian variety.—64. The Mongol.—65. The Malay.—66. The Ethiopian.—67. The American.—68. The relation of languages.—69. The limits of physiological and psychological speculation.—70. Man material and intellectual.—71. Connection between the physical and the intellectual.—72. Personal identity.—73. Analysis of the constituents of the human body.—74. The absurd consequences of materialism.—75. Further difficulties from the question of personal identity.—76. The body said to change altogether once a month.—77. The intellectual part however suffers no change—materialism disproved.—78. Regularity of moral and intellectual phenomena.—79. Difference between them and physical phenomena.—80. Freedom of will does not prevent these phenomena, considered collectively, from observing general laws.—81. Example of statistical phenomena.—82. Frequency of marriages.—83. Constant proportion of unequal marriages.—84. Proportion of illegitimate children.—85. Prevalence of crime, and proportion of acquittals.—86. Acts of forgetfulness—number of unaddressed letters posted.—87. General conclusion.

55. THE mean duration of life in England and Wales during the 40 years ending with the year 1840, varied from thirty-one to thirty-seven years, the variation, however, not being regular, and its mean value being thirty-four years.

56. A similar calculation applied to the population returns in France during the 36 years ending with 1852, showed a progressive increase of the mean duration of life. During the first eight years, ending with 1824, the mean length of life was 31·8 years, and during the last eight years, ending with 1852, it was 36·7. Its mean value for the whole interval of 36 years being 34·2 years, the same as in England.

Now, it will not fail to strike every one that this term of life is greatly below that which would result from general observation, independently of all statistical results. A person dying at thirty-four would be lamented by all as one taken away prematurely in the prime of life. This discrepancy between the results of statistics and common observation admits of easy explanation. The estimate made by common observation is tacitly based upon a rough average taken of the ages at which those die who have already entered upon the scene of life, and have been recognised by all as members of the human family. The more exact calculations of statistics include rigorously all that are born into the world, of whom so large a proportion die in their first year; and as we have seen, not less than 4-10ths in that term of infancy, during which they can scarcely be said to be recognised by common observation as forming part of the population. To render the results of the computation of the absolute duration of life applicable to the 6-10ths which arrive at the adult state, it will only be necessary to augment the computed duration of life in the ratio of 6 to 10. If, therefore, as has been shown, the actual mean duration of life in England and France be 34 years, the mean length of life of those who survive their infancy will be 56 years, which, it is evident, is in complete accordance with common observation.

57. How much the preservation of life during infancy is dependent on parental care, is rendered conspicuously apparent by the melancholy fact established by the statistical returns, that 80 per cent., or four in every five of the children abandoned in France as foundlings, die in their first year.

58. The number of children resulting from each marriage is found by the simple method of comparing the total number of annual legitimate births with the total number of annual marriages. By this process, it appears that the mean number of children to every two marriages in France is seven, and in England eight, these mean results being subject to a very slight variation from year to year.

59. The human race, as is well known, consists of a considerable number of varieties, differing one from another in personal appearance, character, language, in their average degree of

moral and intellectual powers, and in their geographical distribution. Those whose observations have been mainly confined to the extremes of form and colour, and who have not reflected on the wonderful changes to which all organised beings are subject by various external physical causes,—changes which, when once superinduced, are transmitted, not only in man, but in inferior animals, and even in plants, through the series resulting from reproduction,—have viewed the differences observed among the members of the human family, not as characteristics of so many varieties of a single species, but as marks distinguishing different species of the same genus. We have, however, the authority of the greatest living observer of nature, as developed in the animal kingdom, in opposition to this cheerless doctrine.

60. "The permanence of certain types, in the midst of most opposite influences," says Humboldt, "especially of climate, appeared to favour this view, notwithstanding the shortness of the time to which the historical evidence applied; but in my opinion, more powerful reasons lend their weight to the other side of the question, and corroborate the unity of the human race. I refer to the many intermediate gradations of the tint of the skin, and the form of the skull, which have been made known to us, by the rapid progress of geographical science in modern times, to the analogies derived from the history of varieties in animals, both domesticated and wild, and to the positive observations collected respecting the limits of fecundity in hybrids. The greater part of the supposed contrasts, to which so much weight was formerly assigned, have disappeared before the laborious investigations of Tiedemann on the brain of negroes and of Europeans, and the anatomical researches of Vrolik and Weber, on the form of the pelvis. When we take a general view of the dark-coloured African nations, on which the work of Prichard has thrown so much light, and when we compare them with the natives of the Australasian Islands, and with the Papuas and Alfourous, we see that a black tint of skin, woolly hair, and negro features, are by no means invariably associated. So long as the western nations were acquainted with only a small part of the earth's surface, partial views almost necessarily prevailed. Tropical heat, and a black colour of the skin, appeared inseparable. 'The Ethiopians,' said the ancient tragic poet, Theodectes of Phaselis, 'by the near approach of the Sun-God in his course, have their bodies coloured with a dark sooty lustre, and their hair curled and crisped by his parching rays.' The campaigns of Alexander, in which so many subjects connected with physical geography were originally brought into notice, occasioned the first

discussion on the problematical influence of climate on nations and races." *

61. Thus it appears that according to the principles admitted by the most eminent physiologists and naturalists, whether assenting or not to the doctrines of Christianity, there is nothing in the natural differences observable between different parts of the human race distributed over the globe, which is incompatible with that part of the narrative of the origin of mankind, consigned to the Hebrew Scriptures, which traces the whole human race to a single pair and constitutes them therefore as members of a common family.

62. Naturalists and physical geographers have distributed by various classifications these varieties of men, and have generally given them the somewhat vague and improper name of races. Thus Blumenbach classifies them into five races, called the Caucasian, the Mongolian, the American, the Ethiopian, and the Malay. Some authorities reduce this number to four, regarding the Malay merely as a variety of the Ethiopian.

Dr. Prichard, on the other hand, classifies the human family into seven races, which he calls :—

The Iraunian,
The Turanian,
The American,
The Hottentots and Bushmen,
The Negroes,
The Papuas,
And the Alfourous.

This division is objected to by Humboldt, and does not appear to have obtained general acceptation.

63. The Caucasian race (fig. 20), p. 49, in which the population of Europe is included, is distinguished by the beauty of the oval form of the head and countenance; by the large facial angle, amounting to about 90°; by the consequent upright forehead; the horizontal direction of the eyes; the absence of all projection of the cheeks; fine smooth hair; and the fair tint of the skin. They are, however, still more remarkable for the high degree of perfection to which their moral and intellectual faculties speedily attain; a quality which has rendered them the most civilised people of the globe. They occupy all Europe, western Asia as far as the Ganges, and the northern part of Africa. They have derived their name of Caucasian from the supposition that they came originally from the country north of Mount Caucasus, lying between the Caspian and the Black Sea. Although generally fair, they include various

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* Cosmos, vol. i. p. 352, translation.

shades, from the extreme fairness of the red-haired northern to the swarthy inhabitants of certain parts of the Spanish peninsula and of North Africa.

64. The Mongol variety (fig. 21) p. 65, differs in several respects from the Caucasian. Their face is flat; their forehead low, oblique, and angular; their cheek-bones salient; their eyes small, and set obliquely; the chin slightly prominent; the beard sparse; the hair long, straight, and black; and the complexion a yellow or sallow olive.

The languages spoken by the Mongol variety are extremely different from those of the Caucasian, being for the most part monosyllabic. This variety is spread eastwards over the countries occupied chiefly by the Caucasian races. They are encountered in the great desert of Central Asia, where the Kalmucks and other Mongol tribes are still nomadic. Almost the whole population of the eastern part of Siberia is Mongol; but the nation which forms the most remarkable part of this race is the Chinese, whose vast empire was, of all parts of the world, the first civilised; although the exclusive spirit of their laws and customs, which has raised a barrier between them and the rest of mankind, has kept them stationary for ages.

65. The Malay variety occupies the islands of the Indian Archipelago, New Zealand, Chatham Islands, the Society Group, the Philippines and Formosa, and several of the Polynesian Islands. They are dark; have lank, coarse, and black hair; flat faces; and eyes obliquely set. In their moral and social qualities, they vary extremely in different localities; some being active and ingenious, mild and gentle, and considerably advanced in the arts of life; while others are ferocious, vindictive, daring, and predatory. To this variety are generally referred a considerable part of the population of the extreme north of Europe, such as the Greenlanders, Laplanders, Samoides, and Esquimaux.

66. The Ethiopian variety, or Negro (fig. 22), is characterised by his compressed skull, small facial angle, flat nose, salient jaws, thick lips, woolly and crisped hair, and black skin. The habitation of this variety is south of Mount Atlas, and is spread over all the remainder of the African continent, Madagascar, Australia, Mindanao, Gillolo, the islands of Borneo, Sumbawa, Timor, and New Ireland. It consists of several sub-varieties, such, for example, as the Mozembics, the Bushmen, and the Hottentots.

67. The American variety is generally characterised by a copper-coloured skin, sparse beard, and long black hair. They differ extremely, however, one from another; some tribes manifesting a close analogy to the Mongols, others approaching close to the external characters of Europeans; the nose is generally

prominent, like the European; the eyes being large, regular, and disclosed by widely opened lids.

68. The question of the descent of all these varieties from a common origin, is closely connected with the analysis of languages. Nothing affords a more convincing proof of identity of origin than the discovery of similar forms of expression and terms, having like roots in the tongues spoken by distant people. "But here," observes Humboldt, "as in all fields of ideal speculation, there are many illusions to be guarded against, as well as a rich prize to be attained. Positive ethnographical studies, supported by profound historical knowledge, teach us that a great degree of caution is required in these investigations concerning nations, and the language spoken by them at particular epochs. Subjection to a foreign yoke, long association, the influence of a foreign religion, a mixture of races, even when comprising only a small number of the more powerful and more civilised emigrating race, have produced in both continents similar recurring phenomena, viz., in one and the same race two or more entirely different families of languages, and in nations differing widely in origin, idioms belonging to the same linguistic stock. Great Asiatic conquerors have been most powerfully instrumental in the production of striking phenomena of this nature.

"But language is an integral part of the natural history of the human mind; and, notwithstanding the freedom with which the mind pursues perseveringly, in happy independence, its self-chosen direction under the most different physical conditions,—notwithstanding the strong tendency of this freedom to withdraw the spiritual and intellectual part of man's being from the power of terrestrial influences, yet is the disenthralment never completely achieved. There ever remains a trace of the impression which the natural disposition has received from climate, from the clear azure of the heavens, or from the less serene aspect of a vapour-loaded atmosphere. Such influences have their place among those thousand subtle and evanescent links in the electric chain of thought, from whence, as from the perfume of a tender flower, language derives its richness and its grace."

By maintaining the unity of the human species, we at the same time repel the cheerless assumption of superior and inferior races of men. There are families of nations more readily susceptible of culture, more highly civilised, more ennobled by mental cultivation than others, but not in themselves more noble. All are alike designed for freedom; for that freedom which in ruder conditions of society belongs to individuals only, but where states are formed, and political institutions enjoyed, belongs of right to the whole community. "If," says Wilhelm von Humboldt, "we would point to an idea which all history throughout its course discloses as ever establishing more firmly and extending more widely its salutary empire,—if there is one idea which contributes more than any other to the often-contested, but still more often misunderstood, perfectibility of the whole human species,—it is the idea of our common humanity tending to remove the hostile barriers which prejudices and partial views of every kind have raised between men; and to cause all mankind, without distinction of religion, nation, or colour, to be regarded as one great fraternity aspiring towards one common end, the free development of their moral faculties. This is the ultimate and highest object of society; it is also the direction implanted in man's nature, leading towards the indefinite expansion of his inner being. He regards the earth and the starry heavens as inwardly his own, given to him for the exercise of his intellectual and physical activity. The child longs to pass the hills or the waters which surround his native dwelling, and his wish indulged, as the bent tree springs back to its first form of growth, he longs to return to the home which he had left; for by a double aspiration after the unknown future and the unforgotten past, after that which he desires and that which he has lost, man is preserved by a beautiful and touching instinct from exclusive attachment to that which is present. Deeply rooted in man's most innate nature, as well as commanded by his highest tendencies, the full recognition of the bond of humanity, of the community of the whole human race with the sentiments and sympathies which spring therefrom, becomes a leading principle in the history of man." *

69. When we come to trace the conduct of man as an individual member of the social body and to connect it with his physical organisation, we tread upon the interesting ground which forms the confines between the legitimate territories of the physiologist and psychologist, between the provinces of the natural philosopher and the theologian; and however closely our vocation and habitudes have attached us to the contemplation and investigation of mere physical laws, we cannot forbear to throw a passing glance into the spiritual world.

70. Man's nature, according to the admission of all, is a compound of the material and the intellectual. According to some, to whom, on that account, the name of *materialists* has been given, the intellectual is a mere function or property of the material part of our nature. According to others, the intellectual is a function of a spiritual essence, which is independent of our material organi-

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* Cosmos, translation, p. 354.

sation, though inseparably connected with it during human life. The name of *spiritualists* has, accordingly, been given by contradistinction to the latter.

71. Our nature being thus compound, let us see how far we can trace the connection between its mere physical part and the thinking and intelligent principle which abides in it.

72. There is a principle called in metaphysics personal identity, which consists in the internal consciousness by which each individual knows his past existence, so as to be able, with the greatest certainty of which the judgment of our minds is susceptible, to identify himself existing at any given moment with himself, existing at any former time and place. Nothing in human judgment can exceed the clear certitude which attends this consciousness. The Duke of Wellington, on the eve of his death at Walmer, had an assured certainty that he was himself the same individual intelligent thinking being, who, on the 18th of June, 1815, commanded at Waterloo the allied armies. Now to what, let us ask, did this intense conviction and consciousness of identity apply? What was there in common between the individuals who died at Walmer and who commanded at Waterloo? The reply to this question will require that we shall recur for a moment to our physical organisation.

73. The human body consists of bones, flesh and blood, each of which is, however, itself a compound substance, and the whole is impregnated in a large proportion with water. Thus, the quantity of blood in an average body is 20 lbs., of which 15 lbs. are water, the other 5 lbs. consisting of those material constituents which are necessary for the supply of the growth or the repair of the body. The flesh, commonly so called, is pervaded by blood-vessels, and therefore, strictly speaking, is a combination of flesh and blood. In like manner, the bones are pervaded to their very centres by innumerable blood-vessels, so minute as to be microscopic, by which their growth is supplied and their waste repaired. Taking, however, the terms flesh, blood, and bone in their proper meaning, excluding from each the water with which it is impregnated, and excluding from the flesh and bone the blood which pervades them respectively, the material constituents of an average human body may be thus stated:—

Bone	14 lbs.
Flesh and blood	24
Water	116

The bone, when submitted to analysis, is shown to consist of certain earthy matter, the chief part of which is lime and a substance called *gelatine;* this gelatine itself being a compound, one half of which is pure charcoal, called by chemists *carbon*, and the other a combination of the gases which constitute common air and water. From this analysis it follows that, in round numbers, the 14 lbs. of bone which enter into the composition of the human body, omitting minute fractions and insignificant quantities, consist of 10 lbs. of lime, 2 lbs. of charcoal, combined with 2 lbs. weight of the gases just mentioned.

A similar analysis of flesh and blood shows that they consist, in nearly equal parts, of charcoal and the same gases, so that the 24 lbs. weight of these substances which enter into the composition of an average body, are resolved into 12 lbs. of charcoal, combined with an equal weight of the gases already mentioned.

Thus, in fine, the ultimate materials of the average human body, are 14 lbs. of charcoal and 10 lbs. of lime, impregnated with 116 lbs. of water, and 14 lbs. weight of the gases which form air and water, that is, *oxygen*, *nitrogen*, and *hydrogen*.

74. Now those who think that the intellectual principle residing in the human body is nothing more than a quality or a property arising from the matter composing it, must be able to imagine how 14 lbs. of charcoal, 10 lbs. of lime, and 116 lbs. of water can be so mixed up with 14 lbs. of air as to make a material thing—machine let us call it—which can feel, think, judge, remember, and reason. Let us try to imagine, for example, the possibility of such a mass of charcoal, lime, and water discovering the existence, position, and motion of the planet Neptune before it was ever seen; of ascertaining the periodicity of the planetary inequalities, countless ages before many of these inequalities had passed through one of their periods; of inventing the printing press, the ship, the steam-engine, and the electric telegraph; of composing "Paradise Lost;" of producing the Transfiguration and the Antinous, or of designing the Parthenon!

But it will be answered, that the power of intelligence is ascribed not to the mere inert materials of the human body, but to their organisation. What, then, is organisation? Let us not be misled by a long and learned word. Organisation is, and can be, but some particular way of arranging the parts of which any thing is composed. Thus, a given number and weight of stones may be arranged in a thousand different ways, so as to compose as many different structures, but each such structure is still a mere mass of stone. It is true that the simple material elements which we have enumerated above may be, and are, curiously combined and arranged, so as to produce the human body. But after this is accomplished, we are left as far as ever from any explanation as to how the mere arrangement and peculiar juxta-position of the material atoms, thus composing such a body, can produce the prodigious powers of intellect which have been developed in the history of the progress of the human mind.

75. But even admitting a supposition apparently so impossible, the question of personal identity, which we have referred to above, will raise an insuperable objection to it. Physiologists and anatomists have proved that the matter which composes our bodies is subject to continual change. Every part of our organisation, even to the innermost cores of our bones, is subject to this never-ceasing process of mutation. The food which we take into our stomachs contains, combined with some other matters, all the constituents necessary to compose our bodies. In the process of digestion, those parts which are unsuited to our bodies are rejected, and the several suitable parts passing into the blood, are carried by it through the circulating apparatus to all parts of the system; to the bones, as well as to the flesh and softer parts; the peculiar constituents necessary for the maintenance of each part respectively being deposited there in the proper proportion, and the waste carried away. This process of constant renovation and removal of used-up matter—of offal, as it were—goes on equally throughout the bones as throughout the softer parts. Now, it will be evident that, in such an unceasing process of rejection and renovation, the entire mass of matter composing the body must in a certain period, longer or shorter, undergo a complete change, so that, corporeally speaking, an individual, at any given period of his life, has not in his entire composition a single material atom which he had at a certain previous period. It was the opinion of former anatomists and physiologists, that the body undergoes this complete change of the matter composing it every seven years; but more recent and exact observations and calculations, founded upon rigorous analysis of the phenomena of digestion, circulation, respiration, and other less important functions, have proved this estimate to err by excess.

The 116 lbs. weight of water which forms three-fourths of the matter composing our bodies, is rejected with great rapidity in respiration, transpiration, and natural discharge. The carbon is expired with each action of the lungs in large quantities, combined with oxygen, another constituent of our bodies, in the form of carbonic acid. The lime escaping in other ways is rejected from our bones, and replaced by a fresh supply. There is not a movement of the body, whether voluntary or involuntary; not an action of a member, a muscle, or a nerve; not a pulsation of the heart or of an artery; not a peristaltic motion of the intestines, which is not the proximate cause of the rejection of used-up matter and the demand for a fresh supply from the digestive apparatus, just as in a machine the wear and tear of the parts is proportional to the force and continuance of their motions.

76. Although the rapidity with which the materials of the body are thus changed varies in comparing one individual with another, according to their varying habitudes and occupations, it appears that a total change of the material constituents of the body takes place within an interval much shorter than was supposed by the early physiologists. According to some authorities, the average length of this interval does not exceed thirty days. It is, however, generally agreed that it is a very brief period.*

77. This then being the case, let us again ask what is it that was identical in the Duke of Wellington dying at Walmer in Sept. 1852, with the Duke of Wellington commanding at Waterloo in June, 1815? Assuredly it was not possible that there should have been a single particle of matter common to his body on the two occasions. The interval consisting of thirty-seven years and two months, the entire mass of matter composing his body must have undergone a complete change several hundred times—yet no one doubts that there was *something* there which *did not* undergo a change except in its relation to the mutable body, and which possessed the same thought, memory, and consciousness, and constituted the personal identity of the individual; and since it is as demonstrable as any proposition in geometry that *that something* which thus abode in the body, retaining the consciousness of the past, could not have been an atom, or any number of atoms, of matter, it must necessarily have been something *not matter*, that is to say, something *spiritual.*

Habituated for so long a period to the rigorous logic of physics and mathematics, I confess I can see nothing in its results more conclusive than this proof of the existence of a spiritual essence connected with the human organisation. At this point, however, the support which the physical inquirer can offer to the theologian terminates. If there is nothing in the disorganisation of the human body and the phenomena of death to demonstrate the simultaneous destruction of the spiritual principle, the existence of which is thus established, there is, on the other hand, nothing to prove its continued existence, and for that we are thrown upon the resources of revelation, and this might indeed have been foreseen; for if the continued existence of the spirit, or, in other words, a future state, were capable of demonstration by the ordinary faculties of the mind, it would have been incompatible with the divine economy to have rendered it the subject of revelation. God does not suspend the laws of nature to reveal by miraculous means those truths which are discoverable by the exercise of our natural faculties.

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* We are not aware of any dissentient from the complete periodical change of matter composing the body, except Professor Milne Edwards, who, without absolutely denying the principle, thinks that it has not been satisfactorily demonstrated.

78. As the motions and changes produced upon inert matter are physical and mechanical, so human actions are moral and intellectual phenomena. By duly comparing together the former, we are enabled to arrive at generalisations which are the expression of laws, the knowledge of which enables us to foresee, with certainty and precision, how any proposed bodies will comport themselves at any future time, and in any given place, under given conditions. It might, therefore, be naturally expected that the moral and intellectual phenomena of human actions, coming as truly within the range of natural facts as mere physical phenomena, could be equally classified and generalised, and that, consequently, natural laws might be equally established, by the knowledge of which this latter class of phenomena could, under given conditions, be predicted as clearly and certainly as the former.

79. An essential difference, however, between the two classes of phenomena renders a corresponding distinction in the expression of the general laws to which they are subject, necessary. Bodies consisting of mere inert masses of matter are susceptible of no motion save what they derive from the operation of external forces; and when such forces are given, their effects can be calculated and predicted. But the moral and intellectual phenomena here referred to, proceed from an internal and spontaneous act of the will of the individual, which cannot be known antecedently by the individual himself, and still less by others. The will also being absolutely free, the individual may, under given conditions, act in any conceivable manner; and consequently, as regards such an individual, the actions cannot be reduced like physical facts to a general law. Men being thus free agents, and their actions being subject to impulses arising from characters, temperaments, passions, surrounding excitements and personal circumstances infinitely various, it might naturally be expected that the record of the actions of any large society of individuals, such as the population of a city, province, or country, would present a confused and heterogeneous mass of facts altogether unsusceptible of rule, law, or generalisation; and that, consequently, such record preserved of the past would throw no light whatever upon the probable future of the conduct of such a multitude of free agents.

80. Careful and accurate analyses of the acts of men, so far as

they have been registered in public records entitled to confidence, prove, however, that such is not the case; and that although they individually act with perfect freedom of will, yet their acts collectively conform to laws scarcely less rigorous than that of gravitation, and that, consequently, although the freedom of individual will renders it impossible that the individual acts can be predicted, the same impossibility is not at all applicable to collective acts. On the contrary, statistical records prove incontestably that acts which, taken individually, cannot for a moment be doubted to proceed from the impulses of a free and independent will, taken collectively, recur with as much regularity and precision as the fall of a heavy body by gravitation. It is true that such acts, when classified and generalised, give average results from which the individual cases depart more or less on the one side than on the other; but this is no more than takes place with the physical phenomena of inert matter, all of which oscillate round a mean state, the departures from which have received the name of *perturbations*. In moral and intellectual, as well as in physical and mechanical phenomena, there are also perturbations, but, like the latter, these are also confined within narrow limits. The sole difference in the two classes of natural effects being, that in the one case the condition of bodies may be predicted individually, while in the other it can only be predicted collectively.

81. Those who have prosecuted their researches most extensively in the modern science of Statistics, have proved that the effects of the free will of individuals composing large societies completely neutralise each other, and that such communities taken collectively act as if the whole body had by common consent agreed to follow a certain prescribed course of conduct, not only in matters which might be imagined to be more or less of common interest, but even in those in which no feeling could be imagined to be engaged, save the will, taste, personal inclination, or even caprice, of the individual.

82. There is, perhaps, no act of our lives which so exclusively concerns and interests us personally as that of marriage. Although parents and friends must be admitted to exercise more or less influence, yet, in the main, individuals of the different sexes are united together by their personal choice and inclination. This being the case, it might be imagined that the frequency of marriages, and the relative ages of the parties contracting them, would be as various as the tastes, feelings, inclinations, and personal characters of the individuals composing the community. Yet we find that such is not the case; but that, on the contrary, not only the frequency of marriages, but the relative ages of the parties contracting them, are subject to laws quite as rigorous as

those which govern the motions of the solar system. Thus we find, that in the same country, in a series of successive years, the same average number of marriages are contracted, the departures from the average being, like the planetary inequalities, small and self-compensatory. If there is a small excess in one year above the average, there is sure to be a corresponding deficiency in another.

Thus, for example, in England and Wales during the five years from 1845 to 1849 inclusive, the average number of marriages was 142800, and the actual number in each year varied from this average by not more than a few hundreds. In 1851 and 1852, with an increased population, the average number was increased to 156000, from which the variations were equally inconsiderable. In countries, however, where statistical registers are kept with more circumstantial precision than in England, results affording more striking illustrations of these principles may be obtained. In Belgium, for example, to the statistics of which the labours and talents of M. Quetelet have been directed, some very remarkable circumstances bearing on this question have been developed. Thus, it appears that, for a series of years before and after 1840, the average number of marriages contracted in that country was 29130. How completely obedient the population was in the fulfilment of this statistical law, may be seen by the following exact number of marriages contracted in the five years succeeding 1840:—

YEARS.	MARRIAGES.
1841	29876
1842	29023
1843	28220
1844	29326
1845	29210

Thus it appears that in 1841, 1844, and 1845, the number of marriages exceeded, while in 1842 and 1843 they fell just as far short of the average; just as the velocity of a planet near its perihelion exceeds, and near its aphelion falls short, of its mean motion.

83. But this is neither the only, nor by any means the most remarkable, example of the play of general laws in human actions, which, of all others, must be admitted to be the most completely voluntary. Thus, for example, when a man of 30 chooses a wife above 60, he can scarcely be imagined to be controlled by the influence of parents. Yet it appears that the frequency of such marriages is as regular as the annual motion of the sun. Take the following examples. In Belgium, the average number of men not above 30 marrying women above 60 annually is 6, and the

departures from this either way is usually limited to 5 or 7. If in one year there are 7 such marriages, it is sure to be preceded or followed immediately or mediately by another year in which the number is only 5. Again, the number of men between 30 and 45 contracting marriage with women above 60 is annually 18, subject to a small occasional variation one way or the other. In the same way, it appears that the number of men from 45 to 60 marrying women above 60 is annually 27.

The same regularity is found to characterise the number of marriages between couples within any other prescribed limits of comparative age.

84. The number of children resulting from each marriage cannot be considered as depending on will. But assuredly the calling into the world of illegitimate children must be admitted to have the character of a voluntary act; yet it is found, that in each country, the annual number of illegitimate children bears a fixed ratio to the number of marriage-born. In France and Belgium this ratio is 1 to 13. In England the proportion is found to be exactly the same. and this appears to occur, from year to year, in both countries with all the regularity of physical law.

85. The statistics of crime being especially susceptible of exact record, have been submitted to the same careful examination by M. Quetelet, from whose researches it appears, that in the same country the same number of crimes of the same description are committed annually; and this curious result is found equally to attend those classes of crimes which it would seem most impossible to foresee. But, connected with these criminal statistics, there is a circumstance still more curious and remarkable. It necessarily happens, in the administration of criminal justice, that, through the want of sagacity in the examining magistrates, and a multitude of fortuitous circumstances surrounding the accused, a considerable number of guiltless persons are brought to trial. Now, will it be believed, that such is the prevalence of general laws, that even in this class of moral phenomena, founded on the results of fallible judgment, a rigorous law prevails, and we find that, in each country, the proportion of persons charged with offences who are acquitted, is from year to year the same? Thus, for instance, in France, 39 in every 100 of those accused are as regularly acquitted as if the decisions of the juries were made by putting 61 black balls and 39 white ones into a box, and deciding the fate of the criminals by ballot.

86. It is not only, however, voluntary acts which are subject to this numerical regularity. Collectively speaking, persons remember and forget certain things with as much regularity as if memory and attention were the result of wheel-work. A very

common instance of forgetfulness is presented by persons posting letters without any address written upon them. The number of times this act of obliviousness annually happens is known with the greatest precision, inasmuch as such letters are transferred to and recorded in a bureau specially devoted to the purpose in each post-office. Now, it is found by the Post-Office returns in England and France, that the number of these unaddressed letters in each country is almost exactly the same from year to year. In London the number of such letters is about 2000, being at the rate of above 6 per day.

But connected with this is another circumstance equally remarkable. A certain proportion of these letters is found to contain money and other valuable enclosures; and, like the whole number, this proportion is also invariable.

87. The conclusion at which we arrive then is, that the great principle in virtue of which the Author of nature carries out His purposes by the operation of general laws is not, as it would first appear, incompatible with the freedom of human agency, and therefore with man's moral responsibility. The same character of generality attaches to the laws which govern the moral and intellectual phenomena of human actions, considered collectively, as those which attach to mere physical phenomena. But these laws not being applicable to human actions, considered individually, leave free will and moral responsibility inviolate.

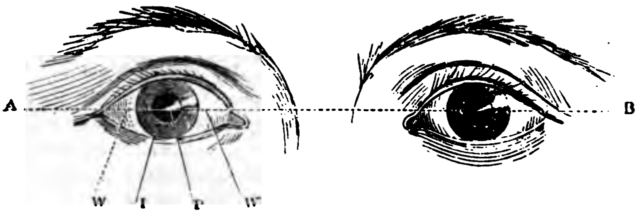


Fig 1.

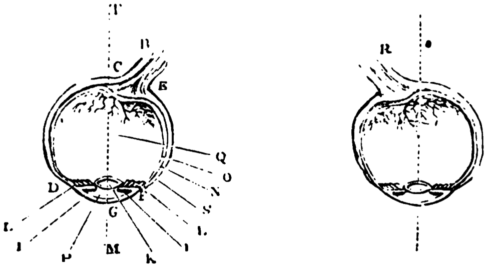


Fig. 2.

THE EYE.

CHAPTER I.

1. Pleasures and advantages of the power of vision.—2. Reasons why a knowledge of the structure and functions of the eye is desirable.—3. Description of the eye.—4. Sclerotica and cornea.—5. Aqueous humour, pupil, and iris.—6. Crystalline humour and ciliary processes.—7. Choroid.—8. Retina and vitreous humour.—9. Axis of the eye and optic nerve.—10. Numerical data.—11. Limits of the play of the eye. — 12. Achromatism of the eye. — 13-16. How vision is caused.—17. Conditions of perfect vision.—18. Distinctness of the image.—19. Parallel rays.—20, 21. Defects of vision and their remedies. — 22-24. Power of adaptation. — 25-29. Limits of this power.—30, 31.—Causes of defective vision.—32. Magnitude of the image on the retina.—33. Apparent magnitude defined. —34-37. Nature of its variation.—38-40. Diminutiveness of the pictures on the retina.—41. Sufficiency of illumination.

1. Of all the organs of sense, that to which we are most largely indebted is unquestionably THE EYE. It opens to us the widest and most varied range of observation. The pleasures and advantages we derive from it directly and indirectly have neither cessation nor bounds. It guides our steps through the world we

inhabit. It invests us with a space-penetrating power to which there seems to be no practical limit. By the exercise of this power, we enjoy the unspeakable pleasure of surveying the physical universe, consisting of countless myriads of worlds dispersed through the measureless abysses of space, worlds compared with most of which this of ours is of most diminutive dimensions. These stupendous globes roll in silent majesty round remote suns which warm and illuminate distant spheres, and collected in vast groups, are often presented to our eye as mere nebulous specks, but when viewed with high telescopic aid, blaze into stellar masses of the most dazzling splendour. System after system of worlds like our own are thus displayed before us, which, according to all analogy, are similarly peopled, and destined to fulfil like destinies in the moral economy of creations,—theatres of life and intelligence teeming with evidence of the incessant play of boundless power, wisdom, and goodness.

Although the eye, strictly speaking, is cognisant only of light and colours, yet from an habitual comparison of combinations and tints of colour with the forms of bodies, as ascertained by the sense of touch, we are enabled, with the greatest facility, promptitude, and precision, to recognise by the sight, the forms, magnitudes, motions, distances, and positions, not only of the objects which surround us, and which we can approach, but also of those constituting the material universe, which are inaccessible.

This vast range of observation, however, great as it is, forms but a small part of the sources of pleasure and advantage supplied by this organ. We have, besides, the inestimable advantages and the great moral powers which arise from the ability it bestows upon us to acquire knowledge through the study of books. It enables us to converse with and derive instruction from the most learned, the most wise, and the most virtuous of our own and all former ages; and although those who have the misfortune to be deprived of this important organ, can, to some small extent, replace it by the ear, aided by the eye of another; yet this, and all other expedients contrived for their relief, supply results infinitely small and insignificant compared with those which are obtained by the organ itself.

2. The eye, considered in itself apart from its uses, is a most interesting and instructive object. It affords beyond comparison the most beautiful example of design, structure, and contrivance, that is to be found in the animal economy. Nowhere do we find so remarkable an adaptation of means to an end, of means consisting of the most profound combination of scientific principles, and an end manifesting the operation of a will directed by the most boundless beneficence.

This organ is, for these reasons, a subject of inquiry and exposition, which must be regarded with the most lively interest by every one, whatever be his station, who is endowed with the least understanding or reflection. But besides the general considerations here developed, it is also to be remembered that, without a previous knowledge of the structure and functions of the eye, it is impossible to comprehend the use and application of the innumerable optical instruments which have been invented to aid its defects, whether natural or accidental; to repair the ravages of time, and to supply to age a renovated and re-invigorated organ of vision; to replace the diseased optical membrane removed by the knife of the surgeon, and thus restore sight where absolute blindness had ensued; to bring within the range of accurate vision objects rendered indistinctly visible, or altogether invisible, either by reason of their remoteness or minuteness. These admirable instruments can be easily rendered intelligible, provided a general knowledge of the structure and functions of the eye be first obtained, but not otherwise.

We purpose, therefore, to devote the present tract to a popular and simple exposition of the eye, and more particularly, the human eye.

3. The eyes, as they exist in the human species, have the form, as is well known, of two spheres, each about an inch in diameter, which are surrounded and protected by strong bony sockets placed on each side of the upper part of the nose. The external coating of these spheres is lubricated by a fluid secreted in adjacent glands, and spread upon them from time to time by the action of the eye-lids in winking.

The eye-balls are moved by muscles connected with them within the socket upon the principle known in mechanics as the ball and socket joint.

A front view of the eyes and surrounding parts is shown in fig. 1, a section of them made by a horizontal plane through the line A B, which passes through the centre of the front of the eye-balls, being shown in fig. 2 (see p. 49).

4. The external coating C D F E consists of a strong and tough membrane, called the *sclerotica,* or sclerotic coat. A part of this membrane is visible when the eye-lids are open at W, and is called the *white of the eye.* In this part of the eye-ball there is a circular opening, covered by a thin and perfectly transparent shell D G F, called the *cornea.* This cornea is more convex than the general surface of the eye-ball, and may be compared to a watch-glass. It is connected round its edge with the sclerotica, which differs from it, however, both in colour and opacity, the sclerotica being white and opaque, while the cornea is perfectly colourless

and transparent. The thickness of the cornea is everywhere the same.

The cornea covers that part of the front of the eye which is coloured, and is terminated round the coloured part at the commencement of the white of the eye.

5. Within the cornea is a small chamber filled with a transparent liquid, called the *aqueous humour*, partially divided by a thin annular partition I, called the iris, in the centre of which is a circular aperture P, called the *pupil*. The *iris* is a membraneous substance varying in colour in different individuals, which gives the peculiar colour to the eye. The pupil presents the appearance of a black spot in the centre of the coloured part. A front view of the iris and pupil is given at I and P, and a section is indicated by the same letters in fig. 2.

6. The membrane containing the aqueous humour is terminated at its posterior part by a substance in the form of a double convex lens, which contains another transparent liquid, called the *crystalline humour*. This lens K is somewhat greater in diameter than the pupil, and is supported by a ring of muscles, called the *ciliary processes* (represented at L), in such a position that its axis passes through the centre of the pupil.

Thus the crystalline and the ciliary processes, with the cornea, include the membrane containing the aqueous humour.

7. Within the sclerotica is a second coat N, called the *choroid*. This is a vascular membrane which lines the internal surface of the sclerotic coat, and which terminates in front in the ciliary processes, by which the crystalline lens is set in it in the same manner as the cornea is set in the sclerotic coat.

Some anatomists maintain that the iris is only a continuation of the choroid, and that the cornea is a continuation of the sclerotic coat, which there becomes transparent. The inner surface of this choroid coat is covered with a slimy pigment of an intensely black colour, by which the reflection of the light which enters the eye is prevented.

8. A third coat, represented at O, called the *retina*, from the resemblance of its structure to network, lines this black coating.

The internal chamber Q of the eye-ball is filled with a transparent liquor, called the *vitreous humour*, which is included in a membraneous capsule, called the hyaloid.

Thus between the cornea and the posterior surface of the eye there are three successive humours; the aqueous, contained by the cornea; the crystalline, contained by the crystalline lens; and the vitreous, which fills the inner and larger chamber of the eye-ball.

9. A straight line M T passing through the centre of the cornea,

coinciding with the axis of the crystalline lens, and through the centre of the eye-ball, is called the *optical axis*, or the *axis of the eye.*

At a point of the posterior surface of the eye-ball between the optical axis M T and the nose, the sclerotic coat is formed into a tube, which leads backwards and upwards to the brain. This tube contains within it the *optic nerve*, which at the point C E, where it enters the eye-ball, spreads out over the inner surface of the choroid and forms the retina, and includes the *hyaloid capsule* containing the vitreous humour.

The retina must therefore be regarded as nothing more than the continuation and diffusion of the optic nerve.

The retina, which in dissection admits of being easily separated from the choroid, is absolutely transparent, so that the light or colours which enter the inner chamber of the eye are not intercepted by it, but penetrate it as they would any other thin and perfectly transparent substance, and are only arrested by the black coating spread upon the choroid.

10. The following are the average numerical data connected with the eye:—

	100ths of an inch.
Radius of sclerotic coating	39 to 43
Radius of cornea	28 — 32
External diameter of iris	43 — 47
Diameter of pupil	12 — 28
Thickness of cornea	4
Distance of pupil from centre of cornea	8
Distance of pupil from centre of crystalline	4
Radius of anterior surface of crystalline	28 — 39
Radius of posterior surface of crystalline	20 — 24
Diameter of crystalline	39
Thickness of crystalline	30
Length of optic axis	87 — 95

11. The limits of the play of the eye-ball are as follows:—The optic axis can turn in the horizontal plane through an angle of 60° towards the nose, and 90° outwards, giving an entire horizontal play of 150°. In the vertical direction it is capable of turning through an angle of 50° upwards and 70° downwards, giving a total vertical play of 120°.

12. When an image of any object is formed by a lens composed of a single piece of glass or other transparent substance, it is always tinged more or less at its edges with the prismatic colours, giving it a sort of iridescence. This constituted a defect of the telescope, which seemed so irremediable that many astronomers had recourse by preference to reflectors, in which no such effect is produced. At length it was discovered that this defect could be completely

removed by lenses, composed of two species of glass, having different refracting powers, and whose curvatures are mutually adapted according to principles established in optics.

Now, it is a curious and highly interesting fact, that the eye, which, as we know, is entirely free from this defect, owes its perfection in this respect to the application of precisely the same optical principle in its structure, so that if the first inventors of the telescope had only thought of copying more closely the structure of the eye, they would have discovered sooner the principle of ACHROMATISM, the name given to this precious quality of lenses, from two Greek words, signifying the absence of colour.

13. The structure of the eye being thus understood, it will be easy to explain the effect produced within it by luminous or illuminated objects placed before it.

Let us suppose rays of light proceeding from any luminous object, such as the sun, incident upon that part of the eye-ball which is left uncovered by the open eye-lids.

Those rays which fall upon the white of the eye, W, fig. 1, render visible that part of the eye-ball. Those rays which fall upon the cornea pass through it. The exterior rays fall upon the iris, by which they are reflected, and render it visible. The internal rays pass through the pupil, are incident upon the crystalline, which, being transparent, is also penetrated by them, from which they pass through the vitreous humour, and finally reach the posterior surface of the inner part of the eye, where they penetrate the transparent retina, and are received by the black surface of the choroid, upon which they produce an illuminated spot.

The aqueous humour being more dense than the external air, and the surface of the cornea, which includes it, being convex, rays passing from the air into it will be rendered by a general law of optics more convergent, or less divergent.

In like manner, the anterior surface of the crystalline lens being convex, and that humour being more dense than the aqueous, a further convergent effect will be produced.

Again, the posterior surface of the crystalline being convex towards the vitreous humour, and this latter humour being less dense than the crystalline, another convergent effect will take place. These rays passing successively through these three humours, are rendered at each surface more and more convergent.

14. If an object be placed before the eye, pencils of rays will proceed from it, and penetrate the successive humours; and if these pencils be brought to a focus at the posterior surface, an inverted image of the object will be formed there, exactly as it would be formed by lenses composed of any transparent media

whose refracting powers would correspond with each of the humours.

15. That this phenomenon is actually produced, may be rendered experimentally manifest by taking the eye-ball of an ox recently killed, and dissecting the posterior part, so as to lay bare the choroid. If the eye thus prepared be fixed in an aperture in a screen, and a candle be placed before it at a distance of eighteen or twenty inches, an inverted image of the candle will be seen through the retina, as if it were produced upon ground glass or oiled paper.

16. It appears, then, that the immediate cause of vision, and the immediate object of perception, is the image thus produced by means of the refracting powers of the humours of the eye.

17. In order, therefore, to perfect vision, the following conditions must be fulfilled:—

1°. The image must be perfectly distinct.

2°. It must have sufficient magnitude.

3°. It must be sufficiently illuminated.

4°. It must continue on the retina for a sufficient length of time.

Let us examine the circumstances which affect these conditions.

18.—1°. DISTINCTNESS OF THE IMAGE.

The image formed on the retina will be distinct or not, according as the pencils of rays proceeding from each point of the object placed before the eye, are brought to an exact focus on the retina or not. If they be not brought to an exact focus on the retina, their focus will be a point beyond the retina, or within it. In either case, the rays proceeding from any part of the object, instead of forming a corresponding point on the retina, will form a spot of greater or less magnitude, according to the distance of the focus of the pencil from the retina, and the assemblage of such luminous spots will form a confused picture of the object. This deviation of the foci of the pencils from the retina is caused by the refracting powers of the eye being either too feeble or too strong. If the refracting powers be too feeble, the rays are intercepted by the retina before they are brought to a focus; if they be too strong, they are brought to a focus before they arrive at the retina.

19. The objects of vision may be distributed into two classes, in relation to the refracting powers of the eye: 1st, Those which are at so great a distance from the eye, that the pencils proceeding from them may be regarded as consisting of parallel rays; 2ndly, Those which are so near that their rays have sensible divergence.

It has been stated that the diameter of the pupil varies from $\frac{1}{8}$ to $\frac{1}{4}$ an inch in magnitude, the variation depending upon a power of dilatation and contraction with which the iris is endued. Taking that diameter at its greatest magnitude of a quarter of an inch, pencils proceeding from an object placed at the distance of three feet would have an extreme divergence amounting to less than half a degree; and if the pupil be in its most contracted state when its diameter is only the one-eighth of an inch, then the divergence of the pencils proceeding from such an object would amount to about fifteen minutes of a degree. It may therefore be concluded, that pencils proceeding from all objects more distant from the eye than two or three feet, may be regarded as consisting of parallel rays.

20. If the refracting power of the humours of the eye be so feeble that rays proceeding from such objects, and which enter the eye in parallel directions, are not rendered sufficiently convergent to come to a focus on the retina, or on the contrary, are so strong as to bring them to a focus before they arrive at the retina, the image produced upon the retina will be confused from the cause just explained.

21. The remedy for such a defect in vision is supplied by the properties of convex and concave lenses.

If the eye possess too little convergent power, a convergent or convex lens is placed before it, which, receiving the parallel pencils, renders them convergent when they enter the pupil, and this enables the eye to bring them to a focus on the retina, provided the power of the lens be equal to the deficient convergence of the eye.

If, on the other hand, the convergent power of the eye be too great, so that the parallel rays are brought to a focus before arriving at the retina, a divergent or concave lens is placed before the eye, by means of which parallel pencils are rendered divergent before they enter the pupil; and the power of the lens is so adapted to the convergent power of the eye, that the rays shall be brought to a focus on the retina.

The two opposite defects of vision here indicated are generally called, the one *weak-sightedness* or *far-sightedness*, and the other *near-sightedness.*

If the objects of vision be placed so near the eye that the rays composing the pencils which proceed from them have sensible divergence, then the foci of these rays within the eye will be at a distance from the optical centre greater than the principal focus, which is the name given to the focus of parallel rays. If, therefore, in this case, the principal focus fall upon the retina, the focus of rays proceeding from such near objects would fall beyond it, and consequently the image on the retina would be indistinct.

22. It follows, therefore, that eyes which see distant objects at the greater class of distances would see indistinctly all objects at less distances, unless there were in the eye some means of self-adjustment, by which its convergent power may be augmented. Such means of self-adjustment are provided, which operate within certain limits, by which we are enabled so to accommodate the eye to the divergence of the pencils proceeding from near objects, that the same eyes which are capable of seeing distinctly objects so distant as to render the rays of the pencils sensibly parallel, are also capable of seeing with equal distinctness objects at distances varying from ten to twelve inches and upwards.

23. By what means the convergent power of the humours is thus varied is not certainly known, but that such means of self-adjustment exist may be proved by the following experiment:—

Let a small black spot be made upon a thin transparent plate of glass, and let it be placed at a distance of about twelve inches from the eye. If the eye be directed to it, the spot will be seen as well as distant objects visible through the glass. Let the attention be earnestly directed to the black spot, so that a distinct perception of its form may be produced. The objects visible at a distance will then be found to become indistinct.

But if the attention be directed more to the distant objects, so as to obtain a distinct perception of them, the perception of the black spot on the glass will then become indistinct. It is evident, therefore, that when the eye accommodates itself so as to form upon the retina a distinct image of an object at twelve inches distance, the image produced by objects at great distances will become indistinct; and that, on the other hand, when the eye so accommodates itself as to render the image produced on the retina by distant objects distinct, the image produced by an object at two inches distance will become indistinct.

24. It is evident, therefore, that the power of the eye to refract the pencils of light incident upon it, is to a certain extent under the control of the will; but by what means this change in the refracting power of the organ is made is not so apparent. Various hypotheses have been advanced to explain it. According to some, the form of the eye-ball, by a muscular action, is changed in such a manner as to increase the length of the optic axis, and thus to remove the posterior surface of the retina to a greater distance from the crystalline, when it is necessary to obtain a distinct view of near objects; and, on the contrary, to elongate the transverse diameter of the eye, and shorten the optic axis so

as to bring the retina closer to the crystalline, when it is desired to obtain a distinct view of distant objects.

According to others, this change of form is only effected in the cornea, which being rendered more or less convex by a muscular action gives a greater or less convergent power to the aqueous humour.

According to others, the eye accommodates itself to different distances by the action of the crystalline, which is moved by the ciliary processes either towards or from the cornea, thus transferring the focus of rays proceeding from it within a certain limit of distance to and from the retina; or, by a similar action of the ciliary processes, the crystalline lens may be supposed to be rendered more or less convex, and thus to increase or diminish its convergent power.

25. Whatever be the provisions made in the organisation of the eye, by which it is enabled to adapt itself to the reception of divergent pencils proceeding from near objects, the power with which it is thus endued has a certain limit. Thus eyes, which see distinctly distant objects, and which therefore bring parallel rays to a focus on the retina in their ordinary state, are not capable of seeing distinctly objects brought nearer to them than ten or twelve inches. The power of accommodating the vision to different rays is therefore limited to a divergence not exceeding that which is determined by the diameter of the pupil compared with a distance of ten or twelve inches. Now, as the diameter of the pupil is most contracted when the organ is directed to such near objects, we may assume it at its smallest magnitude at one-eighth of an inch, and therefore the divergence of a pencil proceeding from a distance of twelve inches would be $\frac{1}{96}$th, and the angle of divergence would therefore be very nearly half a degree.

It may, therefore, be assumed that eyes adapted to the vision of distant objects are in general incapable of seeing distinctly objects from which pencils have greater divergence than this, or which is the same, objects placed at less than ten or twelve inches from the eye.

26. In the case of eyes whose convergent power is too feeble to bring pencils proceeding from distant objects to a focus on the retina, they will be in a still greater degree inadequate to bring pencils to a focus which diverge from near objects; and consequently such eyes will require to be aided, for near as well as distant objects, by the interposition of convergent lenses. It would, however, be necessary to provide lenses of different convergent powers for distant and near objects, the latter requiring a greater convergent power than the former; and in general the nearer the objects viewed, the greater the convergent power required from the lens.

27. In the case of eyes whose convergent power is so great as to bring pencils proceeding from distant objects to a focus short of the retina, and which therefore, for such distant objects, require the intervention of divergent lenses, distinct vision will be attained without the interposition of any lens, provided the object be placed at such a distance that the divergence of the pencils proceeding from it shall be such that the convergent power of the eye brings them to a focus on the retina.

Hence it is that eyes of this sort are called *short-sighted*, because they can see distinctly such objects only as are placed at the distance which gives the pencils proceeding from them such a divergence, that the convergent power of the eye would bring them to a focus on the retina.

28. If it be desired to ascertain the focal length of the divergent lens which such an eye would require to see distant objects distinctly, it is only necessary to ascertain at what distance it is enabled to see distinctly the same class of objects without the aid of a lens. A lens having a focal length equal to this distance will enable the eye to see distant objects distinctly, because such a lens would give the parallel rays a divergence equal to the divergence of pencils proceeding from a distance equal to its focal length.

29. Persons are said to be more or less near-sighted, according to the distance at which they are enabled to see objects with perfect distinctness, and they accordingly require, to enable them to see distant objects distinctly, diverging lenses of greater or less focal length.

As persons who are enabled to see distant objects distinctly have the power of accommodating the eye so as to see objects at ten or twelve inches' distance, so short-sighted persons have a similar power of accommodation, but within proportionally smaller limits. Thus a short-sighted person will be enabled to see distinctly objects placed at distances from the eye varying from four or five inches upwards, according to the degree of short-sightedness with which he is affected.

30. The two opposite defects of vision which have been mentioned, arising from too great or too little convergent power in the eye, may arise, either from a defect in the quality of the humours or in the form of the eye. Thus near-sightedness may arise from too great convexity in the cornea or in the crystalline, or it may arise from too great a difference of density between the aqueous humour and the crystalline, or between the crystalline humour and the vitreous, or both of them; or, in fine, it may arise from defects both of the form and of the relative densities of the humours.

31. In a certain class of maladies incidental to the sight, the humours of the eye lose in a greater or less degree their trans-

parency, and the crystalline humour is more especially liable to this. In such cases vision is sometimes recovered by means of the removal of the crystalline humour, in which case the organ is reduced to two humours, the aqueous and the vitreous ; but as the eye owes in a greater degree to the crystalline than to the other humours the convergent power, it is necessary in this case to supply the place of the crystalline by a very strong convergent lens placed before the eye.

32.—2°. MAGNITUDE OF THE IMAGE ON THE RETINA.

In order to obtain a perception of any visible object, it is not enough that the image on the retina be distinct, it must also have a certain magnitude.

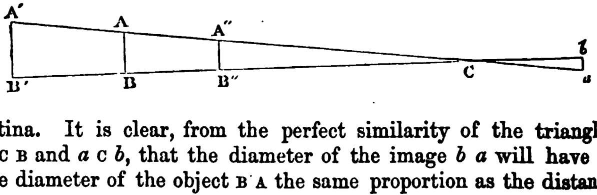
Let us suppose that a white circular disk, one foot diameter, is placed before the eye at a distance of 57½ feet.

The axes of the pencils of rays proceeding from such disk to the eye will be included within a cone, whose base is the disk, and whose vertex is in the centre of the eye.

These axes, after intersecting at the centre of the eye, will form another cone, whose base will be the image of the disk formed upon the retina. The common angle of the two cones will in this case be 1°.

Let A B (fig. 3), be the diameter of the disk. Let C be the centre of the eye, and let *b a* be the diameter of the image on the retina. It is clear, from the perfect similarity of the triangles A C B and *a* C *b*, that the diameter of the image *b a* will have to the diameter of the object B A the same proportion as the distance *a* C of the retina from the centre C has to the distance A C of the object from the same centre. Therefore in this case, since one-half the diameter of the eye is but half an inch, and the distance A C is in this case supposed to be 57½ feet, the magnitude of the diameter *b a* of the image on the retina will be found by the following proportion :—

Fig. 3.



$$a\,b : \text{A B} : : \tfrac{1}{2} : 57\tfrac{1}{2} \times 12 = 690,$$

Therefore we have

$$a\,b = \frac{\frac{1}{2} \times \text{A B}}{690} = \frac{6}{690} = \frac{1}{115}.$$

The total magnitude, therefore, of the diameter of the image on the retina would in this case be the $\frac{1}{115}$th part of an inch; yet such is the exquisite sensibility of the organ, that the object is in this case distinctly visible.

If the disk were removed to twice the distance here supposed, the angle of the cone C would be reduced to half a degree, and the diameter of the image on the retina would be reduced to one-half its former magnitude, that is to say, to the $\frac{1}{230}$th part of an inch. If, on the other hand, the disk were moved towards the eye, and placed at half its original distance, then the angle C of the cone would be 2°, and the diameter of the picture on the retina would be double its first magnitude, that is to say, the $\frac{2}{115}$th of an inch.

In general, it may therefore be inferred that the magnitude of the diameter of the picture on the retina is increased or diminished in exactly the same proportion as the angle of the cone C, formed at the centre of the eye, is increased or diminished.

33. This angle is called the visual angle or apparent magnitude of the object; and when it is said that a certain object subtends at the eye a certain angle, it is meant that lines drawn from the extremities of such object to the centre of the eye form such angle.

The *apparent magnitude* of an object must not be confounded with its apparent superficial magnitude, the term being invariably applied to its *linear magnitude*. The apparent superficial magnitude varies in proportion to the square of the apparent magnitude.

Thus, for example, when the disk A B is removed to double its original distance from the eye, the apparent magnitude, or the angle C, is diminished one-half, and consequently the diameter *a b* of the picture on the retina is also diminished one-half; and since the diameter is diminished in the ratio of 2 to 1, the superficial magnitude of the image, or its area, will be diminished in the proportion of 4 to 1.

34. It is clear from what has been stated also, that when the same object is moved from or towards the eye, its apparent magnitude varies inversely as its distance; that is, its apparent magnitude is increased in the same proportion as its distance is diminished, and *vice versâ*.

It is easy to perceive that the objects which are seen under the same visual angle will have the same apparent magnitude. Thus let A′ B′ (fig. 3), be an object more distant than A B, and of such a magnitude that its highest point A′ shall be in the continuation of the line C A, and its lowest point B′ in the continuation of the line C B. The apparent magnitude of A′ B′ will then be measured by the angle at C. This angle will therefore at the same time represent the apparent magnitude of the object A B and of the object A′ B′. It is evident that an eye placed at C will see every point of the object A B upon the corresponding points of the object

A′ B′; so that if the object A B were opaque, and of a form similar to the object A′ B′, every point of the one would be seen upon a corresponding point of the other. In like manner, if an object A″ B″ were placed nearer the eye than A B, so that its highest point may lie upon the line C A, and its lowest point upon the line C B, the object being similar in form to A B, would appear to be of the same magnitude. Now it is evident that the real magnitudes of the three objects A″ B″, A B, and A′ B′, are in proportion to their respective distances from the eye; A′ B′ is just so much greater than A B, and A B than A″ B″, as C B′ is greater than C B, and as C B is greater than C B″.

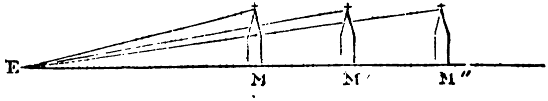
Thus it appears that if several objects be placed before the eye in the same direction at different distances, and that the real linear magnitudes of these objects are in the proportion of their distances, they will have the same apparent magnitude.

35. A striking example of this principle is presented by the case of the sun and moon. These objects appear in the heavens equal in size, the full moon being equal in apparent magnitude to the sun. Now it is proved by astronomical observation that the real diameter of the sun is, in round numbers, four hundred times that of the moon; but it is also proved that the distance of the sun from the earth is also, in round numbers, four hundred times greater than that of the moon. The distances, therefore, of these two objects being in the same proportion as their real diameters, their visual or apparent magnitudes are equal.

36. It is evident from what has been explained, that objects which have equal apparent magnitudes, and are therefore seen under equal visual angles, will have pictures of equal magnitude on the retina, a fact which proves that the visual angle is the measure of the apparent magnitude.

37. If the same object be moved successively to increasing distances, its apparent magnitude will be diminished in the same proportion, exactly as its distance from the eye is increased. Thus, if L M (fig. 4), be such an object, its apparent magnitude at the distance E M will be measured by the angle L E M, at the distance E M′ by the angle L′ E M′, and at the distance E M″ by the angle L″ E M″; and when the actual magnitude L M bears a

Fig. 4.



small proportion to the distance, it is shown by the principles of geometry that the angle L′ E M′ is less than the angle L E M in the same proportion as E M′ is greater than E M, and that the angle L″ E M″ is less than L E M in the same proportion as E M″ is greater than E M.

38. Nothing can be more calculated to excite our wonder and admiration than the distinctness of our perception of visible objects, compared with the magnitude of the picture on the retina, from which immediately we receive such perception.

39. If we look at the full moon on a clear night, we perceive with considerable distinctness by the naked eye the lineaments of light and shade which characterise its disk. Now let us consider only for a moment what are the dimensions of the picture of the moon formed on the retina, from which alone we derive this distinct perception.

The disk of the moon subtends a visual angle of half a degree, and consequently, according to what has been explained, the diameter of its picture on the retina will be $\frac{1}{230}$th part of an inch, and the entire superficial magnitude of the image from which we derive this distinct perception is only the $\frac{1}{52900}$th part of a square inch; yet within this minute space, we are able to distinguish a multiplicity of still more minute details. We perceive, for example, forms of light and shade, whose linear dimensions do not exceed one-tenth part of the apparent diameter of the moon, and which therefore occupy upon the retina a space whose diameter does not exceed the $\frac{1}{5000000}$th part of a square inch.

40. To take another example, the figure of a man 70 inches high, seen at a distance of 40 feet, produces an image upon the retina the height of which is about one-fourteenth part of an inch. The face of such an image is included in a circle whose diameter is about one-twelfth of the height, and therefore occupies on the retina a circle whose diameter is about the $\frac{1}{170}$th part of an inch; nevertheless, within this circle, the eyes, nose, and lineaments are distinctly seen. The diameter of the eye is about one-twelfth of that of the face, and therefore, though distinctly seen, does not occupy upon the retina a space exceeding the $\frac{1}{4000000}$th of a square inch.

If the retina be the canvas on which this exquisite miniature is delineated, how infinitely delicate must be its structure, to receive and transmit details so minute with such marvellous precision; and if, according to the opinion of some, the perception of these details be obtained by the retina *feeling* the image formed upon the choroid, how exquisitely sensitive must be its touch!

41.—3°. SUFFICIENCY OF ILLUMINATION.

It is not enough for distinct vision that a well-defined picture of the object shall be formed on the retina. This picture must be sufficiently illuminated to affect the sense, and at the same time not be so intensely illuminated as to overpower the organ.

Thus it is possible to conceive a picture on the retina so extremely faint as to be insufficient to produce sensation, or, on the other hand, so intensely brilliant as to dazzle the eye, to destroy the distinctness of sense, and to produce pain.

When we direct the eye to the sun, near the meridian, in an unclouded sky, we have no distinct perception of his disk, because the splendour is so great as to overpower the sense of vision, just as sounds are sometimes so intense as to be deafening.

That it is the intense splendour alone which prevents a distinct perception of the solar disk in this case is rendered manifest by the fact that if a portion of the solar rays be intercepted by a coloured glass, or by a thin cloud, a distinct image of the sun will be seen.

When we direct the eye to the firmament on a clear night, there are innumerable stars which transmit light to the eye, and which therefore must produce some image on the retina, but of which we are altogether insensible, owing to the faintness of the illumination. That the light, however, does enter the eye and arrive at the retina is proved by the fact that if a telescope be directed to the stars in question, so as to collect a greater quantity of their light upon the retina, they will become visible.

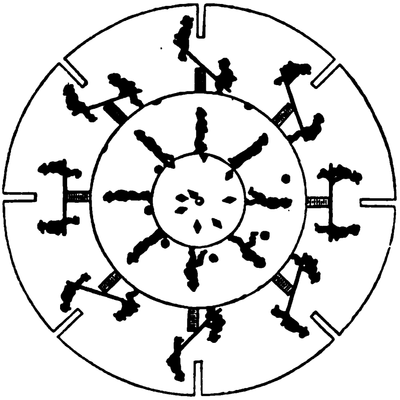


Fig. 8.—THE THAUMATROPE.

THE EYE.

CHAPTER II.

42. Power of accommodation of the eye.—43, 44. Apparent brightness of luminous objects.—45-47. Intensity of brightness.—48-57. The image must continue a sufficient time upon the retina to enable that membrane to produce a perception of it—Various illustrations of this.—58. Conditions which determine apparent motion.—59. How affected by distance.—60. Example.—61. When imperceptible.—62. Motion of the firmament.—63. Objects in rapid motion invisible.—64-66. Duration of the impression on the retina.—67. Optical toys.—68, 69. Coincidence of the optical and geometrical centres of the eye.—70. Ocular spectra and accidental colours.—71. Why visible objects do not appear inverted.—72. The seat of vision.—73-75. The optic nerve insensible to light.

42. The eye possesses a certain limited power of accommodating itself to various degrees of illumination. Circumstances which are familiar to every one render the exercise of this power evident.

If a person, after remaining a certain time in a dark room, pass suddenly into another room strongly illuminated, the eye suffers instantly a degree of inconvenience, and even pain, which causes the eyelids to close; and it is not until after the lapse of a certain time that they can be opened without inconvenience.

The cause of this is easily explained. While the observer remains in the darkened or less illuminated room, the pupil is dilated so as to admit into the eye as great a quantity of light as the structure of the organ allows of. When he passes suddenly into the strongly illuminated room, the flood of light arriving through the widely dilated pupil acts with such violence on the retina as to produce pain, which necessarily calls for the relief and protection of the organ. The iris, then, by an action peculiar to it, contracts the dimensions of the pupil so as to admit proportionally less light, and the eye is opened with impunity.

Effects the reverse of these are observed when a person passes from a strongly illuminated room into one comparatively dark, or into the open air at night. For a certain time he sees nothing, because the contraction of the pupil, which was adapted to the strong light to which it had previously been exposed, admits so little light to the retina that no sensation is produced. The pupil, however, after a while dilates, and, admitting more light, objects are perceived which were before invisible.

43. It is sometimes inferred, though erroneously, that the apparent splendour of the image of a visible object decreases as the square of the distance increases. This would be the case in the strictest sense, if, while the object were withdrawn from the eye to an increased distance, its image on the retina continued to have the same magnitude; for, in this case, the absolute brightness of each point composing such image would diminish as the square of the distance increases, and the area of the retina over which such points are diffused would remain the same; but it must be considered, that as the object retires from the eye the superficial magnitude of the image on the retina is diminished in the same proportion as the square of the distance of the object from the eye is increased. It therefore follows that while the points composing the image on the retina are diminished in the intensity of their illumination, they are collected into a smaller space, so that what each point of the image on the retina loses in splendour, the entire image gains by concentration.

44. If the sun were brought as close to the earth as the moon, its apparent diameter would be 400 times greater, and the area of its apparent disk 160000 times greater than at present, but the apparent brightness of its surface would not be in any degree increased. In the same manner, if the sun were removed to ten times its present distance, it would appear under a visual angle ten times less than at present, as in fact it would to an observer

on the planet Saturn, and its visible area would be a hundred times less than it is, but the splendour of its diminished area would be exactly the same as the present splendour of the sun's disk.

The sun seen from the planet Saturn has an apparent diameter ten times less than it has when seen from the earth.

The appearance from Saturn will then be the same as would be the appearance of a portion of the disk of the sun seen from the earth through a circular aperture in an opaque plate, which would exhibit a portion of the disk whose diameter is one-tenth of the whole.

45. When the light which radiates from a luminous object has a certain intensity, it will continue to affect the retina in a sensible manner, even when the object is removed to such a distance that the visual angle shall cease to have any perceivable magnitude. The fixed stars present innumerable examples of this effect. None of these objects, even the most brilliant of them, subtend any sensible angle to the eye. When viewed through the most perfect telescopes they appear merely as brilliant points. In this case, therefore, the eye is affected by the light alone, and not by the magnitude of the object seen.

46. Nevertheless the distance of such an object may be increased to such an extent that the light, intense as it is, will cease to produce a sensible effect upon the retina.

There are seven classes of the fixed stars, diminishing gradually in brightness,* which produce an effect on the retina such as to render them visible to a naked eye. This diminution of splendour is produced by their increased distance. The telescope brings into view innumerable other stars, whose intrinsic splendour is as great as the brightest among those which we see, but which do not transmit to the retina, without the aid of the telescope, enough of light to produce any sensible effect. It is demonstrable, however, that, even without the telescope, they do transmit a certain definite quantity of light to the retina; the quantity of light which they thus transmit, and which is insufficient to produce a sensible effect, having to the quantity obtained by the telescope a ratio depending upon the proportion of the magnitude of the object-glass of the telescope to the magnitude of the pupil.

47. The quantity and intensity of the light transmitted by an external object to the retina, which is sufficient to produce a perception of such object, depends also upon the light received at the

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* The term magnitude is used in astronomy, as applied to the fixed stars, to express their apparent brightness; no fixed star, however splendid, subtends any sensible angle.

same time by the retina from other objects present before the eye. The proof of this is, that the same objects which are visible at one time are not visible at another, though equally before the eye, and transmitting equal quantities of light of the same intensity to the retina. Thus, the stars are present in the heavens by day as well as by night, and transmit the same quantity of light to the retina, yet they are not visible in the presence of the sun, because the light proceeding from that luminary, directly and indirectly reflected and refracted by the air and innumerable other objects, is so much greater in quantity and intensity as to overpower the inferior and much less intense light of the stars. This case is altogether analogous to that of the ear, which when under the impression of loud and intense sounds, is incapable of perceiving sounds of less intensity, which nevertheless affect the organ in the same manner as they do when, in the absence of louder sounds, they are distinctly heard.

Even when an object is perceived, the intensity of the perception is relative, and determined by other perceptions produced at the same time. Thus, the moon seen at night is incomparably more splendid than the same moon seen by day or in the twilight, although in each case the moon transmits precisely the same quantity of light, of precisely the same intensity, to the eye; but in the one case the eye is overpowered by the superior splendour of the light of day, which dims the comparatively less intense light proceeding from the moon.

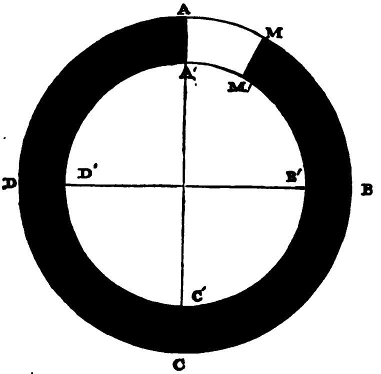
48.—4°. THE IMAGE MUST CONTINUE A SUFFICIENT TIME UPON THE RETINA TO ENABLE THAT MEMBRANE TO PRODUCE A PERCEPTION OF IT.

The velocity with which light is propagated through space is at the rate of about 200000 miles per second. Its transmission, therefore, from all objects at ordinary distances to the eye may be considered as instantaneous. The moment, therefore, any object is placed before the eye an image of it is formed on the retina, and this image continues there until the object is removed. Now it is easy to show experimentally that an object may be placed before the eye for a certain definite interval of time, and that a picture may be painted upon the retina during that interval without producing any perception or any consciousness of the presence of the object.

To illustrate this, let a circular disk A B C D, fig. 5, about twenty inches in diameter, be formed in card or tin, and let a circle A′ B′ C′ D′ be described upon it, about two inches less in radius than the disk, so as to leave between the circle and the disk a zone about two inches wide. Let the entire zone be blackened, except the space A M M′ A′, forming about the one-twentieth of it.

Let the disk thus prepared be attached to the back of a blackened screen, so as to be capable of revolving behind it, and let a hole one inch in diameter be made in the screen at any point, behind which the zone A B C D is placed. If the disk be now made to revolve behind the screen, the hole will appear as a circular white spot so long as the white space A M passes behind it, and will disappear, leaving the same black colour as the screen during the remainder of the revolution of the disk. The hole will therefore be seen as a white circular spot upon the black screen during one-twentieth of each revolution of the disk. If the disk be now put in motion at a slow rate, the white hole will be seen on the screen during one-twentieth of each revolution. If the velocity of rotation imparted to the disk be gradually increased, the white spot will ultimately *disappear*, and the screen appear of a uniform black colour, although it be certain that during the twentieth part of each revolution, whatever be the rate of rotation, a picture of the white spot is formed on the retina.

Fig. 5.



49. The length of time necessary in this case for the action of light upon the retina to produce sensation may be determined by ascertaining the most rapid motion of the disk which is capable of producing a distinct perception of the white spot. This interval will be found to vary with the degree of illumination. If the spot be strongly illuminated, a less interval will be sufficient to produce a perception of it; if it be more feebly illuminated, a longer interval will be required. The experiment may be made by varying the colour of the space A M of the zone, and it will be found that the interval necessary to produce sensation will vary with the colour as well as with the degree of illumination.

50. Numerous observations on the most familiar effects of vision, and various experiments expressly contrived for the purpose, show that the retina, when once impressed with the picture of an object placed before the eye, retains this impression, sometimes with its full intensity and sometimes more faintly, just as the ear retains for a time the sensation of a sound after the cause which has put the tympanum in vibration has ceased to act. The

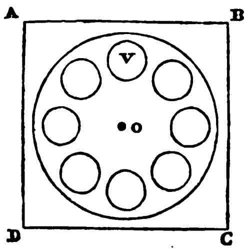
duration of this impression on the retina, after the removal of the visible object which produced it, varies according to the degree of illumination and the colour of the object. The more intense the illumination, and the brighter the colour, the longer will be the interval during which the retina will retain their effects.

51. To illustrate this experimentally, let a circular disk formed of blackened card or tin, of twelve or fourteen inches in diameter, be pierced with eight holes round its circumference, at equal distances, each hole being about half an inch in diameter, as represented in fig. 6.

Let this disk be attached upon a pivot or pin at its centre O to a board A B C D, which is blackened everywhere, except upon a circular spot at V, corresponding in magnitude to the holes made in the circular plate.

Let this spot be first supposed to be white. Let the circular disk be made to revolve upon the point O, so as to bring the circular holes successively before the white spot at V. The retina will thus be impressed at intervals with the image of this circular white spot. In the intervals between the transits of the holes over it, the entire board will appear black, and the retina will receive no impression. If the disk be made to revolve with a very slow motion, the eye will see the white spot at intervals, but if the velocity of rotation be gradually increased, it will be found that the eye will perceive the white spot permanently represented at V, as if the disk had been placed with one of its holes opposite to it without moving. It is evident, therefore, that in this case the impression produced upon the retina, when any hole is opposite the white spot, remains until the succeeding hole comes opposite to it, and thus a continued perception of the white spot is produced.

Fig. 6.



If the white spot be illuminated in various degrees, or if it be differently coloured, the velocity of the disk necessary to produce a continuous perception of it will differ. The brighter the colour and the stronger the illumination, the less will be the velocity of rotation of the disk which is necessary to produce a continuous perception of the spot.

These effects show that the stronger the illumination and the brighter the colour, the longer is the interval during which the impression is retained by the retina.

52. This continuance of the impression of external objects on the

retina, after the light from the object ceases to act, is also manifested by the fact, that the continual winking of the eyes for the purpose of lubricating the eye-ball by the eye-lid does not intercept our vision. If we look at any external objects, they never cease for a moment to be visible to us, notwithstanding the frequent intermissions which take place in the action of light upon the retina in consequence of its being thus intercepted by the eye-lid.

53. If a lighted stick be turned round in a circle in a dark room, the appearance to the eye will be a continuous circle of light; for in this case the impression produced upon the retina by the light, when the stick is at any point of the circle, is retained until the stick returns to that point.

54. In the same manner, a flash of lightning appears to the eye as a continuous line of light, because the light emitted at any point of the line remains upon the retina until the cause of the light passes over the succeeding points. In the same manner, any objects moving before the eye with such a velocity that the retina shall retain the impression produced at one point in the line of its motion until it passes through the other points, will appear as a continuous line of light or colour.

55. But to produce this effect, it is not enough that the body change its position so rapidly that the impression produced at one point of its path continues until its arrival at another point; it is necessary, also, that its motion should not be so rapid as to make it pass from any of the positions which it successively assumes before it has time to impress the eye with a perception of it; for it must be remembered, as has been already explained, that the perception of a visible object presented to the eye, though rapid, is not instantaneous.

The object must remain present before the organ of vision a certain definite time, and its position must continue upon the retina during such time, before any perception of it is obtained. Now, if the body move from its position before the lapse of this time, it necessarily follows that no perception of its presence, therefore, will be obtained. If, then, we suppose a body moving so rapidly before the eye that it remains in no position long enough to produce a perception of it, such object will not be seen.

56. Hence it is that the ball discharged from a cannon passing transversely to the line of vision is not seen; but if the eye be placed in the direction in which the ball moves, so that its angular motion round the eye as a centre will be slow notwithstanding its great velocity, it will be visible, because, however rapid its real motion through space, its angular motion with respect to the eye (and consequently of the image of its picture on the retina) will

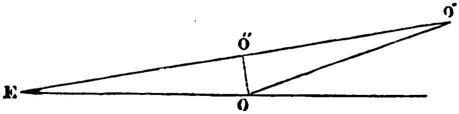
be sufficiently slow to give the necessary time for the production of a perception of it.

57. The time thus necessary to obtain the perception of a visible object varies with the degree of illumination, the colour, and the apparent magnitude of the object. The more intense the illumination the more vivid the colour, and the greater the apparent magnitude the less will be the time necessary to produce a perception of the object.

58. In applying this principle to the phenomena of vision, it must be carefully remembered that the question is affected, not by the real but by the apparent motion of the object, that is to say, not by the velocity with which the object really moves through space, but by the angle which the line drawn from the eye to the object describes per second. Now this angle is affected by two conditions, which it is important to attend to: 1°. the direction of the motion of the object compared with the line of vision; and 2°. by the velocity of the motion compared with the distance of the object. If the object were to move exactly in the direction of the line of vision, it would appear to the eye to be absolutely stationary, since the line drawn to it would have no angular motion; and if it were to move in a direction forming an oblique angle to the line of vision, its apparent motion might be indefinitely slow, however great its real velocity might be.

For example, let it be supposed that the eye being at E, fig. 7, an object O moves in the direction of O O′, so as to move from O to O′ in one second. Taking E as a centre, and E O as a radius, let a circular arc O O″ be described. The apparent motion of the object will then be same as if, instead of moving from O to O′ in one second, it moved from O to O″ in one second.

Fig. 7.



The more nearly, therefore, at right angles to the line of vision the direction of the motion is, the greater will be the apparent motion produced by any real motion of an object.

59. A motion which is visible at one distance may be invisible at another, inasmuch as the angular velocity will be increased as the distance is diminished.

Thus if an object at a distance of 57½ feet from the eye move at the rate of a foot per second, it will appear to move at the rate of one degree per second, inasmuch as a line one foot long at 57½ feet distance subtends an angle of one degree. Now if the eye be removed from such an object to a distance of 115 feet, the apparent motion will be half a degree, or thirty minutes per second; and if it be removed to thirty times that distance, the apparent motion will be thirty times slower. Or if, on the other hand, the eye be brought nearer to the object, the apparent motion will be accelerated in exactly the same proportion as the distance of the eye is diminished.

60. A cannon-ball moving at 1000 miles an hour transversely to the line of vision, and at a distance of 50 yards from the eye, will be invisible, since it will not remain a sufficient time in any one position to produce perception. The moon, however, moving with more than double the velocity of the cannon-ball, being at a distance of 240000 miles, has an apparent motion, so slow as to be imperceptible.

61. The angular motion of the line of vision may be so diminished as to become imperceptible; and the body thus moved will in this case appear stationary. It is found by experience that unless a body move in such a manner that the line of vision shall describe at least one degree in each minute of time, its motion will not be perceptible.

62. Thus it is that we are not conscious of the diurnal motion of the firmament. If we look at the moon and stars on a clear night, they appear to the eye to be quiescent; but if we observe them after the lapse of some hours, we find that their positions are changed, those which were near the horizon being nearer the meridian, and those which were in the meridian having descended towards the horizon. Since we are conscious that this change did not take place suddenly, we infer that the entire firmament must have been in continual motion round us, but that this motion is so slow as to be imperceptible.

Since the heavens appear to make a complete revolution in twenty-four hours, each object on the firmament must move at the rate of 15° an hour, or at the rate of one quarter of a degree a minute. But since no motion is perceptible to the eye which has a less apparent velocity than 1° per minute, this motion of the firmament is unperceived. If, however, the earth revolved on its axis in six hours instead of twenty-four hours, then the sun, moon, stars, and other celestial objects, would have a motion at the rate of 60° an hour, or 1° per minute. The sun would appear to move over a space equal to twice its own diameter each minute, and this motion would be distinctly perceived.

The fact that the motion of the hands of a clock is not perceived is explained in the same manner.

63. If an object which moves very rapidly be not sufficiently

illuminated, or be not of a sufficiently bright colour to impress the retina sensibly, it will then, instead of appearing as a continuous line of colour, cease to be visible altogether; for it does not remain in any one position long enough to produce a sensible effect upon the retina. It is for this reason that a ball projected from a cannon or a musket, though passing before the eye, cannot be seen. If two railway trains pass each other with a certain velocity, a person looking out of the window of one of them will be unable to see the other. If the velocity be very moderate, and the light of the day sufficiently strong, the appearance of the passing train will be that of a flash of colour formed by the mixture of the prevailing colours of the vehicles composing it.

An expedient has been contrived, depending on this principle, to show experimentally that the mixture of the seven prismatic colours, in their proper proportions, produces white light. The colours are laid upon a circular disk surrounding its edge, which they divide into parts proportional to the spaces they occupy in the spectrum. When the disk is made to revolve, each colour produces, like the lighted stick, the impression of a continuous ring, and consequently the eye is sensible of seven rings of the several colours superposed one upon the other, which thus produce the effect of their combination, and appear as white or a whitish grey colour.

64. The duration of the impression upon the retina, after the object producing it is removed, varies according to the vividness of the light proceeding from the object, being longer according as the light is more intense. It was found that the light proceeding from a piece of coal in combustion moved in a circle at a distance of 165 feet, produced the impression of a continuous circle of light when it revolved at the rate of seven times per second. The inference from this would be that in that particular case the impression upon the retina was continued during the seventh part of a second after the removal of the object.

It is from the cause here indicated that forked lightning presents the appearance of a continuous line of light.

65. The duration of the impression on the retina varies also with the colour of the light, that produced by a white object being most visible, and yellow and red being most in degree of durability; the least durable being those tints which belong to the most refrangible lights.

66. The duration of the impression also depends on the state of illumination of the surrounding space; thus the impression produced by a luminous object when in a dark room is more durable than that which would be produced by the same object seen in an illuminated room. This may be ascribed to the greater sensitiveness

of the retina when in a state of repose than when its entire surface is excited by surrounding lights. Thus it is found that while the varying duration of the impression of the illuminated object in a dark room was one-third of a second, its duration in a lighted room was only one-sixth of a second.

67. Innumerable optical toys and pyrotechnic apparatus owe their effect to this continuance of the impression upon the retina when the object has changed its position.

Amusing toys, called thaumatropes, phenakisticopes, phantaskopes, &c., are explained upon this principle. A moving object, which assumes a succession of different positions in performing any action, is represented in the successive divisions of the circumference of a circle, as in fig. 8, in the successive positions it assumes. These pictures, by causing the disk to revolve, are brought in rapid succession before an aperture, through which the eye is directed, so that the pictures representing the successive attitudes are brought one after another before the eye at intervals; the impression of one remaining until the impression of the next is produced. In this manner the eye never ceases to see the figure, but sees it in such a succession of attitudes as it would assume if it revolved. The effect is, that the figure actually appears to pirouette before the eye. The effects of catherine-wheels and rockets are explained in the same manner.

68. The direction in which any part of an object is seen is that of the line drawn from such point through the optical centre of the eye. This line being carried back to the retina determines the place on the retina where the image of such point is found. If the optical centre of the eye were not at the centre of the eye-ball, the direction of this line would be changed with every movement of the eye-ball in its socket; every such movement would cause the optical centre to revolve round the centre of the eye-ball, and consequently would cause the line drawn from the optical centre to the object to change its direction. The effect of this would be that every movement of the eye-ball would cause an apparent movement of all visible objects. Now, since there is no apparent motion of this kind, and since the apparent position of external objects remains the same, however the eye may be moved in its socket, it follows that its optical centre must be at the centre of the eye-ball.

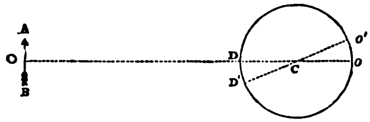
69. Since lines drawn from the various points of a visible object through the centre of the eye remain unchanged, however the eye-ball may move in its socket, and since the corresponding points of the image placed upon these lines must also remain unchanged, it follows that the position of the image formed on the eye remains fixed, even though the eye-ball revolve in the

socket. It appears, therefore, that when the eye-ball is moved in the socket, the picture of an external object remains fixed, while the retina moves under it, just as the picture thrown by a magic lantern on a screen would remain fixed, however the screen itself might be moved.

Thus, if we direct the axis of the eye to the centre O, fig. 9, of any object, such as A B, the image of the point O will be formed at *o* on the retina, where the optical axis D C meets it. The axis of the pencil of rays which proceed from the point O will pass through the centre of the cornea D, through the axis of the crystalline, and through the centre C of the eye-ball, and the image of O will be formed at *o*.

Now, if we suppose the eye to be turned a little to the left, so that the optical axis will be inclined to the line O C at the angle D′ C O, the image of the point O will still hold the same absolute position *o* as before; but the point of the retina on which it was previously formed will be removed to *o*′. The direction of the point O will be the same as before; but the point of the retina on which its image will be formed will be, not at *o*, at the extremity of the optic axis, but at *o*′, at a distance *o o*′ from it, which subtends at the centre C of the eye an angle equal to that through which the optical axis has been turned.

Fig. 9.

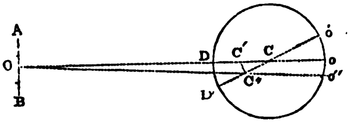


It is evident, therefore, that although the eye in this case be moved round its centre, the point O is still seen in the same direction as before.

But if the optical centre of the eye were different from the centre of the eye-ball, the direction in which the point O would be seen would be changed by a change of position of the eye.

To render this more clear, let C, fig. 10, be the centre of the eye-ball, and C′ the optical centre of the eye. Let the optical axis C D, as before, be first presented to the point O of the object.

Fig. 10.



The image of this point will, as before, be formed at *o*, the point where the optical axis D C meets the retina. Let us now suppose the axis of the eye to be turned aside through the angle D C D′, the optical centre will then be removed from C′ to C″, and the image of *o* will now be formed at the point *o*″, where the line O C″ meets the retina. The direction, therefore, in which O will now be seen, will be that of the line C″ O, whereas the direction in which it was before seen was that of the line C O. The point of the retina at which the image *o* was originally formed is removed to *o*′, while the image is removed to *o*″. Thus there is a displacement not only of the retina behind the image, but also an absolute displacement of the image, and an absolute change in the apparent direction of the object. Since no such change in the apparent direction is consequent upon the movement of the eye in its socket, it follows that the optical centre C′ of the eye must coincide with its geometrical centre C.

70. The continuance of the effect produced by the image of a visible object on the retina after such object has been removed from before the eye, combined with the effect of the image of another object placed before the eye during such continuance of the effect of that which was removed, produces a class of phenomena called *ocular spectra* and *accidental colours.*

The effect produced by a strongly illuminated image formed on the retina does not appear to be merely the continuance of the same perception after the image is removed, but also a certain diminution or deadening of the sensibility of the membrane to other impressions. If the organ were merely affected by the continuance of the perception of the object for a certain time after its removal, the effect of the immediate perception of another object on the retina would be the perception of the mixture of two colours. Thus, if the eye, after contemplating a bright yellow object, were suddenly directed to a similar object of a light red colour, the effect ought to be the perception of an orange colour; and this perception would continue until the effect of the yellow object on the retina would cease, after which the red object would alone be perceived.

Thus, for example, a disk of white paper being placed upon a black ground, and over it a red wafer which will exactly cover it being laid, if, closing one eye, and gazing intently with the other for a few seconds on the red wafer, the red wafer be suddenly removed so as to expose the white surface under it to the eye, the effect ought to be the combination of the perception of red which continues after the removal of the red wafer, with the perception of white which the uncovered surface produces; and we should consequently expect to see a diluted red disk, similar to that which would be produced by the mixture of red with white.

This, however, is not the case. If the experiment be performed as here described, the eye will, on the removal of the red wafer, perceive, not a reddish, but a greenish-blue disk.

In like manner, if the wafer, instead of being red, were of a bright greenish-blue, when removed the impression on the eye would be that of a reddish disk.

These and like phenomena are explained as follows:—

When the eye is directed with an intensity of gaze for some time at the red surface, that part of the retina upon which the image of the red wafer is produced becomes fatigued with the action of the red light, and loses to some extent its sensibility to that light, exactly as the ear is deafened for a moment by an overpowering sound. When the red wafer is removed, the white disk beneath it transmits to the eye the white light, which is composed of all the colours of the spectrum. But the eye, from the previous action of the red light, is comparatively insensible to those tints which form the red end of the spectrum, such as red and orange, but comparatively sensible to the blues and greens, which occupy the other end. It is therefore that the eye perceives the white disk as if it were a greenish-blue, and continues to perceive it until the retina recovers its sensibility for red light.

71. A difficulty has been presented in the explanation of the functions of the eye to which, as it appears to me, undue weight has been given. It has been already explained, that the images of external objects which are depicted on the retina are inverted; and it has accordingly been asked why visible objects do not appear upside down. The answer to this appears to be extremely simple. Inversion is a relative term, which it is impossible to explain or even to conceive without reference to something which is not inverted. If we say that any object is inverted, the phrase ceases to have meaning unless some other object or objects are implied which are erect. If all objects whatever hold the same relative position, none can be properly said to be inverted; as the world turns upon its axis once in twenty-four hours, it is certain that the position which all objects hold at any moment is inverted with respect to that which they held twelve hours before, and to that which they will hold twelve hours later; but the objects as they are contemplated are always erect. In fine, since all the images produced upon the retina hold with relation to each other the same position, none are inverted with respect to others; and as such images alone can be the objects of vision, no one object of vision can be inverted with respect to any other object of vision;

and consequently, all being seen in the same position, that position is called the erect position.

72. Physiologists are not agreed as to the manner in which the perception of a visible object is obtained from the image formed in the interior of the eye. It is certain, however, that this image is the cause of vision, or that the means whereby it is produced are also instrumental in producing the perception of sight. It may also be considered as established that the perception of a visible object is more or less distinct, according to the greater or less distinctness of the image. But it would be a great error to assume that this image on the retina is itself seen, for that would involve the supposition of a second eye, beyond the first, or within it, by which such image on the retina would be viewed. Now, no means of communicating between the image on the retina and the sensorium exist except the usual conduits of all sensation, the nerves.

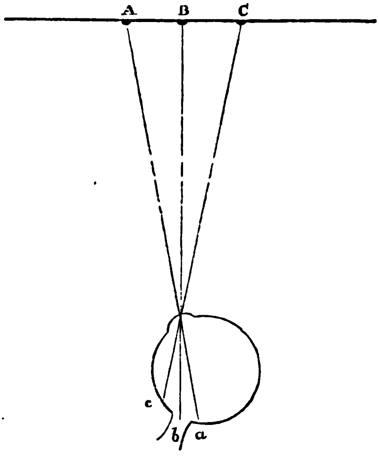
It has been already explained that the optic nerve, after entering the eye at a point near the nose, spreads itself over the interior of the globe of the eye behind the vitreous humour, and that this retina or network is perfectly transparent, the coloured image being formed not properly upon it, but upon the black surface of the choroid coat behind it. Now, it has been maintained, that the functions of vision are performed by this nervous membrane in a manner analogous to that by which the sense of touch is affected by external objects. The membrane of the retina, it is supposed, touching the coloured image, and being in the highest degree sensitive to it, just as the hand is sensitive to an object which it touches, receives from the coloured image an action which, being continued to the brain, produces perception there in accordance with the form and colour of the image upon the choroid. According to this view of the functions of vision, the retina *feels*, as it were, the image on the choroid, and transmits to the sensorium the impression of its colour and figure in the same manner as the hand of a blind person would transmit to the sensorium the form of an object which it touches.

73. If this hypothesis be admitted, it would follow that the retina itself would be incapable of exciting the sense of sight by the mere action of light and colours upon it. This is verified by the fact that when the image produced within the eye is formed upon a point of the optic nerve which has not the choroid behind it, no perception is produced.

In order to prove this, let three wafers be applied in a horizontal line upon a vertical screen, each separated from the other by a distance of two feet. Let the screen be placed before the observer at a distance of about 15 feet, the wafers being on a level with the eye; and let the centre wafer be so placed that a line drawn from the right eye to it shall be perpendicular to the screen. Let the left eye be now closed, and let the right eye be directed to the extreme wafer on the left, but so that all three wafers may still be perceived. Let another person now slowly move the screen, so as to bring it nearer to the observer, maintaining, however, the middle wafer in the direction of the eye at C. It will be found that the screen being so moved to a distance of 10 feet from the eye, the middle wafer will appear to be suddenly extinguished, and the extreme wafers on the right and left will be seen.

74. This remarkable phenomenon is explained by showing that in this particular position of the eye and the screen the image of the middle wafer falls upon the base of the optic nerve when the choroid coat is not under it.

Fig. 11.



This will be rendered more intelligible by reference to fig. 11, where B is the middle wafer, A the left-hand, and C the right-hand wafer. The image of A is formed at *a*, to the right of the optic nerve; and the image of C is formed at *c*, to the left of that nerve. In both these positions the choroid coat is behind the retina. But the image of B is formed at *b*, directly upon the point where the optic nerve issues from the eye-ball, and where the choroid does not extend behind it.

75. Sir David Brewster gives the following experiment as a further argument in support of this hypothesis. In the eye of the *Sepia loligo*, or cuttle-fish, an opaque membranous pigment is interposed between the retina and the vitreous humour, so that if the retina were essential to vision, the impression of the image on this black membrane must be conveyed to it by the vibration of this membrane in front of it. Sir David Brewster also mentions that in young persons the choroid coat, instead of being covered with a black pigment, reflects a brilliant crimson, like that of dogs and some other animals; and imagines that if the retina were affected by the rays which pass through it, this crimson light ought to excite a corresponding sensation, which is not the case.

THE EYE.

CHAPTER III.

76. Why objects are not seen double. — 77. Exceptional cases. — 78. The eye has no direct perception of distance or magnitude. — 79. How distances are estimated.—80. Appearance of the sun and moon when rising or setting.—81. How magnitudes are estimated. —82. Illusion produced in St. Peter's at Rome.—83. Magnitude inferred from distance. — 84. Perception of angular motion.—85. How real direction of motion may be inferred.—86. Examples of the sun and moon. — 87-90. Effect of the motion of the observer—Examples.—91. Angular distance defined. —92. The eye has no direct perception of form—How inferred.—93. Visible area defined. —94. Figure inferred from lights and shadows.—95. Power of distinguishing colours.—96, 97. Absence of this power in particular cases.

76. The question why, having two eyes on which independent impressions are made by external objects, and on the retina of each of which an independent picture of a visible object is formed, we do not see distinct objects corresponding to each individual external object which impresses the organ, is often asked.

The first reflection which arises on the proposition of this question, is why the same question has not been similarly proposed with reference to the sense of hearing. Why has it not been asked why we do not hear double? why each individual sound produced by a bell or a string is not heard as two distinct sounds, since it must impress independently and separately the two organs of hearing?

It cannot be denied, that, whatever reason there be for demanding a solution of the question, why we do not see double? is equally applicable to the solution of the analogous question, why we do not hear double? Like many disputed questions, this will be stripped of much of its difficulty and obscurity by a strict attention to the meaning of the terms used in the question, and in the discussion consequent upon it. If by seeing double it be meant that the two eyes receive separate and independent impressions from each external object, then it is true that we see double. But if it be meant that the mind receives two distinct and independent impressions of the same external object, then a qualified answer only can be given.

If the two eyes convey to the mind precisely the same impression of the same external object, differing in no respect whatever, then they will produce in the mind precisely the same perception of the object; and as it is impossible to imagine two perceptions to exist in the mind of the same external object which are precisely the same in all respects, it would involve a contradiction in terms to suppose that, in such case, we perceive the object double.

If to perceive the object double mean anything, it means that the mind has two perceptions of the same object, distinct and different from each other in some respect. Now, if this distinctness or difference exist in the mind, a corresponding distinctness and difference must exist in the impression produced of the external object on the organs. It will presently appear, that cases do occur in which the organs are, in fact, differently impressed by the same external object; and it will also appear, that in such cases precisely we *do see double*, meaning by these terms, that we have two perceptions of the same object, as distinct from each other as are our perceptions of two different objects.

To render this point more clear, let us consider in what respects it is possible for the impressions made upon the two eyes by the same object to differ from each other.

A visible object impresses the eye with a sense of a certain apparent form, of a certain apparent magnitude, of certain colours, of a certain intensity of illumination, and of a certain visible direction. Now, if the impression produced by the same object upon the two eyes agree in all these respects, it is impossible to imagine that the mind can receive two distinct perceptions of the object, for it is not possible that the two perceptions could differ from each other in any respect, except in some of those just mentioned. Let us suppose the two eyes to look at the moon, and that such object impresses them with an image of precisely the same apparent form and magnitude, of precisely the same colours and lineaments, of precisely the same intensity of illumination, and in precisely the same direction. Now, the impressions conveyed to the mind by each of the eyes corresponding in all these respects, the object must be perceived in virtue of both impressions precisely in the same manner, that is to say, it must be seen in precisely the same direction, of precisely the same magnitude, of precisely the same form, with precisely the same lineaments of light and shade, and with precisely the same brightness or intensity of illumination. It is therefore, in such a case, clearly impossible to have a double perception of the object.

It will be observed, that the same reasoning exactly will be applicable to the sense of hearing. If the same string or the same pipe affect the tympanum of each ear in precisely the same manner, so as to produce a perception of a sound of the same pitch, the same loudness, and the same quality, it is impossible to conceive that two different perceptions can be produced by the two ears, for there is no respect in which it is possible for two such perceptions to differ, inasmuch as by the very supposition they agree in all the qualities which belong to sound.

But, if we could conceive by any organic derangement that the same musical string would produce in one ear the note *ut*, and produce in the other ear the note *sol*, then the same effect would be produced as if these two sounds had been simultaneously heard by the two ears properly organised, and we should have a sense of harmony of the *fifth*.

In like manner, if the two eyes, by any defect of organisation, produced different pictures on the retina, we should then have two perceptions of the same object having a corresponding difference.

It has been already shown, that the apparent visual magnitude of an object, and also that its apparent brilliancy, depend on its distance from the eye.

Now, assuming, as we shall do, unless the contrary be expressed, that the two eyes are similarly constituted, it will follow, that an object whose distance from the two eyes is equal will be seen under the same visual angle, and will therefore have the same apparent magnitude; it will also have the same colour and intensity of illumination, and, in fine, if the distance between the eyes bear an insignificant proportion to the distance of the object from them, the lines drawn from the centre of the eyes to any point on the object will be practically parallel; and since these lines, as has been already explained, determine the direction in which the object is seen, such object will then be seen in the same direction. Now, since the apparent form, the apparent magnitude, the apparent colour, the apparent intensity of illumination, and the apparent direction are the same for both eyes, it is clear that the same impression must be produced upon the senses, and the same perceptions conveyed to the mind; consequently it follows, demonstratively, that all objects which are placed at a distance compared with which the distance between the eyes is insignificant, will convey a single perception to the mind, and will consequently not be seen double.

77. But we have now to consider a different case, which will present peculiar conditions, and consequences of peculiar interest.

Let us suppose an object placed so near the eyes that its distance shall not bear a considerable proportion to the length of the line which separates the centres of the eyes. In this case, the images produced on the retina of the two eyes may differ in magnitude, and intensity of illumination, and even in form, and, in fine, it is clear that the apparent direction of any point on the object as seen by the two eyes will be sensibly different.

In this case, therefore, the two eyes convey to the mind a different impression of the same object; and we may therefore expect that we should see it double, and in fact we do so.

But the observation of this particular phenomenon requires much attention, inasmuch as the perception of which we are conscious is affected not merely by the impression made upon the organ of sense, but by the degree of attention which the mind gives to it. Thus, if the two eyes be differently impressed either by the same or by different objects placed before them, the mind may give its attention so exclusively to either impression, as to lose all consciousness of the other.

Thus, if two stars be at the same time in the field of view of a telescope, as frequently happens, and be viewed together by the eye, we shall be conscious of a perception of both, so long as the attention is not exclusively directed to either; but if we gaze intently on one of them so as to observe its colour, or any other peculiarity attending it, we shall cease to be conscious of the presence of the other. The application of this observation to the question before us will be presently apparent.

Let R L, fig. 12, be the line separating the centres of the two eyes, R representing the centre of the right, and L that of the left eye.

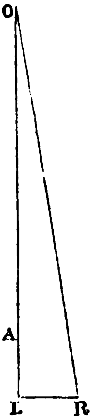


Fig. 12.

Let O be an object, such as the flame of a candle or lamp, seen at the distance of about 40 feet, so that the lines of direction L O and R O converging upon it from the centres of the eyes may be regarded as practically parallel, the distance being about 200 times greater than the distance L R between the eyes. The object O will therefore be seen in the same direction by both eyes, and being at a distance from the two eyes practically equal, will have the same apparent magnitude, form, colour, and intensity of illumination, and, consequently, will be seen single.

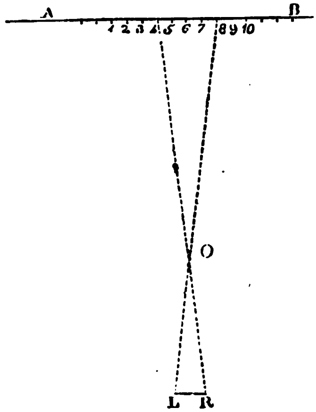
Let a small white rod be held at the distance A, of about 8 inches from the left eye L, and in the line L O, so as to intercept the view of the object O from the left eye. The left eye will then see the rod at A, and not the object O; but the right eye will still see the object O, as before. Now, if the attention be earnestly directed to the object O, the object A will not be perceived; but if the attention be directed to the object A, it will be perceived distinctly, but the object O will be seen through it as if it were transparent.

Now, since the object O cannot be seen by the left eye under the circumstances here supposed, the perception we have of it must be derived from the right eye; nevertheless it is seen in the line L A O, immediately beyond the intercepting wand, and in the same direction, and in the same manner precisely as it would be seen by the left eye L if the intercepting wand were removed. It follows, therefore, that the perception we obtain of the object O by the right eye is precisely the same as that which we should obtain by the left eye if the right were closed, and the intercepting wand A removed. This may therefore be taken as an experimental proof of what, indeed, may seem sufficiently evident, *à priori*, that an object, such as O, placed at a distance so great that lines drawn to it from the centre of the eyes would be practically parallel, produces precisely the same perception through the vision of both eyes.

But when the distance of an object from the eye is so small that the line which separates the eyes bears a considerable proportion to it, the directions in which such an object is seen by the two eyes are different, and it is easy to show that in this case such an object would be seen double.

Let L, and R (fig. 13), as before, be the centres of the two eyes, and let A B be a white screen placed vertically at a distance of 12 or 14 feet, having upon it a horizontal line on a level with the eye, upon which is marked a divided scale 1, 2, 3, 4, 5, 6, 7, 8, 9, 10. Let a black wand be held vertically at O, opposite the middle of the line L R. This wand will be seen by the left eye in the direction of the division 8, and by the right eye in the direction of the division 4, on the screen, and two images o the wand will accordingly be perceived; but, according as the attention is directed to the one or to the other, a consciousness of them will be produced. Thus, by an act of the will we may contemplate only the objects as seen with the left eye, in which case the wand will be seen projected on the screen perpendicular to the line A B, at the 8th division; and by a like act of the will, the attention being directed to the impression produced by the right eye, the wand will be seen projected on the screen at the 4th division of the scale. If the attention be withdrawn from either of these and the wand be viewed indifferently, we shall be conscious of the two images, but not with the same distinctness as that with which we should perceive two wands placed at the 4th and 8th divisions of the scale. It will follow from this, that when we look with both eyes at any object, such as the printed page of a book, at the distance of 8 or 10 inches from the eyes, we have two images of the different parts of the page placed before the eyes, which are seen in different directions, and ought therefore to produce double vision; but this is prevented by habitually directing our attention to one of the two, and neglecting the other.

Fig 13.



That the perception of an object will be double if the directions in which it is seen by the two eyes are different, may also be demonstrated in the following manner:—

It has been already shown that the optical centres of the eyes cannot change their position by the mere action of the muscles which move the eye-balls in their sockets, and that the direction in which any distant object is seen by both eyes is the same, and hence it is perceived single; but if a slight pressure be applied to the eye with the finger, the optical centre of the eye may be moved from its position, so that the direction of the same object seen by it and the other eye will not be the same. A distant object will in this case be seen double, being perceived in one direction by the eye which retains its natural position, and in another by that whose position is deranged by pressure.

78. It has been already explained that two similar objects whose distances from the eye are to each other in the same proportion as their linear dimensions will have the same apparent magnitude.

In like manner, if an object, such as, for example, a balloon, moves from the eye in a direct line, we have no distinct consciousness of its motion, for the line of direction in which it is seen is still the same. It is true that we may infer its motion through the air by the increase or diminution of its apparent magnitude; for, if we have reason to know that its real magnitude remains unchanged, we ascribe almost intuitively the change of its apparent magnitude to the change of its distance; and we consequently *infer* that it is in motion either towards or from us, according as we perceive its apparent magnitude to be increased or diminished. This information, however, as to the motion of a body in a direct line to or from the centre of the eye, is not a perception obtained directly from vision, but an inference of the reason deduced from certain phenomena. It may, therefore, be stated generally, that the eye affords no perception of direct distance, and consequently none of direct motion, the term direct being understood here to express a motion in a straight line to or from the optical centre of the eye.

79. The distance of a visible object is often estimated by comparing it with the apparent magnitude and apparent distance of known objects which intervene between it and the eye.

Thus, the steeple of a church whose real height is unknown cannot by mere vision be estimated either as to distance or magnitude, since the apparent height would be the same, provided its magnitude were greater or less in proportion to its supposed distance. But, if between the steeple and the eye there intervene buildings, trees, or other objects, whose average magnitudes may be estimated, a proximate estimate of the magnitude and distance of the steeple may be obtained.

For example, if the height of the most distant building between the eye and the steeple be known, the distance of that building may be estimated by its apparent magnitude, and the distance of the steeple will be inferred to be greater than this.

80. A remarkably deceptive impression, depending on this principle, is deserving of mention here. When the disc of the sun or moon at rising or setting nearly touches the horizon, it appears of enormous magnitude compared with its apparent size when high in the firmament. Now, if the visual angle which it subtends be actually measured in this case, it will be found to be of the same magnitude. How, then, it may be asked, does it happen that the apparent magnitude of the sun at setting and at

noon are by measure the same, when they are by estimation, and by the irresistible evidence of sense, so extremely different? This is explained, not by an error of the sense, for there is none, but by an erroneous application of those means of judging or estimating distance which in ordinary cases supply true and just conclusions.

When the disc of the sun is near the horizon, a number of intervening objects of known magnitude and known relative distances supply the means of spacing and measuring a part at least of the distance between the eye and the sun; but when the sun is in the meridian, no such objects intervene. The mind, therefore, assigns a greater magnitude to the distance, a part of which it has the means of measuring, than to the distance no part of which it can measure; and accordingly an impression is produced, that the sun at setting is at a much greater real distance than the sun in the meridian; and since its apparent magnitude in both cases is the same, its real magnitude must be just so much greater as its estimated distance is greater. The judgment, therefore, and not the eye, assigns this erroneous magnitude to the disc of the sun.

It is true that we are not conscious of this mental operation. But this unconsciousness is explained by the effect of habit, which causes innumerable other operations of the reason to pass unobserved.

81. As the eye forms no immediate perception of distance, neither does it of form or of magnitude, since, as has been already proved, objects of very different real magnitudes have the same apparent magnitude to the eye, of which a striking example is afforded in the case of the sun and moon. Nevertheless, although the eye supplies no immediate perception of the real magnitude of objects, habit and experience enable us to form estimates more or less exact of these magnitudes by the comparison of different effects produced by sight and touch.

Thus, for example, if two objects be seen at the same distance from the eye, the real magnitude of one of which is known, that of the other can be immediately inferred, since, in this case, the apparent magnitudes will be proportional to the real magnitudes. Thus, for example, if we see the figure of a man standing beside a tree, we form an estimate of the height of the latter, that of the former being known or assumed. Ascribing to the individual seen near the tree the average height of the human figure, and comparing the apparent height of the tree with his apparent height, we form an estimate of the height of the tree.

82. It is by this kind of inference that buildings constructed upon a scale greatly exceeding common dimensions are estimated, and rendered apparent in pictorial representations of them.

On entering, for example, the aisle of St. Peter's at Rome, or St. Paul's at London, we are not immediately conscious of the vastness of the scale of these structures; but if we happen to see at a distant part of the building a human figure, we immediately become conscious of the scale of the structure, for the known dimensions of this figure supply a modulus which the mind instantly applies to measure the dimensions of the whole. For this reason artists, when they represent these structures, never fail to introduce human figures in or near them.

83. It has been explained that the apparent magnitude of objects depends conjointly on their real magnitude and their distance. Although, therefore, the eye does not afford any direct perception either of real magnitude or distance, we are by habit enabled to infer one of these from the other.

Thus, if we happen to know the real magnitude of a visible object, we form an estimate of its distance from its apparent magnitude; and, on the other hand, if we happen to know or can ascertain the distance of an object, we immediately form some estimate of its real magnitude.

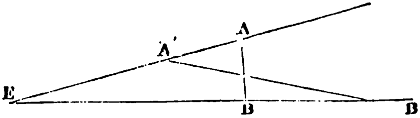
Thus, for example, the height of a human figure being known, if we observe its apparent visual magnitude to be extremely small, we know that it must be at a distance proportionally great. If we know that at 20 feet the figure of a man will have a certain apparent height, and that we find that his figure seen at a certain distance appears to have only one-fifth of this height, we infer that his distance must be about 100 feet.

In like manner, the real magnitude may be inferred from the apparent magnitude, provided the distance be known or can be ascertained. Thus, for example, in entering Switzerland by its northern frontier, we see in the distance, bounding the horizon, the line of the snowy Alps, and the first impression is that of disappointment, their apparent scale being greatly less than we expected; but when we are informed that their distance is sixty or eighty miles, our estimate is instantly corrected, and we become conscious that the real height of mountains which, seen at so great a distance, is what we observe it, must be proportionately vast.

84. When an object moves in any direction which is not in a straight line drawn to or from the centre of the eye, the direction in which it is seen continually changes, and the eye in this case supplies an immediate perception of its motion; but this perception can be easily shown to be one not entirely corresponding to the actual motion of the object, but merely to the continual change of direction which this motion produces in the line drawn from the object to the eye.

Thus, for example, if the eye be at E (fig. 14), any object which moves from A to B will cause the line of direction in which it is seen to revolve through the angle A E B, just as though the body which moves were to describe a circular arc, of which E is the centre and E A the radius. But if, instead of moving from A to B, the body were to move from A′ to B′, the impression which its motion would produce upon the sight would be exactly the same. It would still appear to be moving from the direction E A′ A to the direction E B B′.

Fig. 14.



In fine, the eye affording no perception of direct distance, supplies no evidence of the extent to which the body may change its distance from the eye during its motion, and the apparent motion will be the same as if the body in motion described a circle of which the eye is the centre.

Hence it is that the only motion of which the eye forms any immediate apprehension is angular motion, that is, a motion which is measured by the angle which a line describes, one extremity of which is at the centre of the eye, and the other at the moving object.

85. Though the real direction in which a distant object moves cannot be obtained by the direct perception of vision, some estimate of it may be formed by comparing the apparent angular motion of the object with its apparent magnitude.

Thus, for example, if we observe that the apparent magnitude of an object remains constantly the same while it has a certain apparent angular motion, we infer that its distance must necessarily remain the same, and consequently that it revolves in a circle, in the centre of which the observer is placed; or if we find that it has an angular motion, in virtue of which it changes its direction successively around us, so as to make a complete circuit of 360°, and that in making this circuit its apparent magnitude first diminishes to a certain limit, and then augments until it attains a certain major limit from which it again diminishes, we infer that such a body revolves round us at a varying distance, its distance being greatest when the apparent magnitude is least, and least when its apparent magnitude is greatest. An exact observation of the variation of the apparent magnitude would in such a case supply a corresponding estimate of the variation of the real distance, and would thus form the means of ascertaining the path in which the body moves.

86. An example of this is presented in the cases of the sun and

moon, whose apparent magnitudes are subject, during their revolution round the earth, to a slight variation, being a minimum at one point and a maximum at the extreme opposite point, the variation being such as to show that their motions are made in an ellipse in the focus of which the earth is placed.

87. As the eye perceives the motion of an object only by the change in the direction of the line joining the object with the eye, and as this change of direction may be produced as well by the motion of the observer as by that of the object, we find accordingly that apparent motions are produced sometimes in this manner. Thus, if a person be placed in the cabin of a boat which is moved upon a river or canal with a motion of which the observer is not conscious, the banks and all objects upon them appear to him to move in a contrary direction. In this case the line drawn from the object to the eye is not moved at the end connected with the object, which it would be if the object itself were in motion, but at the end connected with the eye. The change of its direction, however, is the same as if the end connected with the object had a motion in a contrary direction, the end connected with the eye being at rest; consequently the apparent motion of the objects seen which are really at rest, is in a direction contrary to the real motion of the observer.

88. In some cases the apparent motion of an object is produced by a combination of a real motion in the object and a real motion in the observer. Thus, if a person transported in a railway carriage meet a train coming in the opposite direction, both extremes of the line joining his eye with the train which passes him are in motion in contrary directions; that extremity which is at his eye is moved by the motion of the train which carries him, and the other extremity is moved by the motion of the train which passes him. The change of direction of the line is accordingly produced by the sum of these motions; and as this change of direction is imputed by the sense to the train which passes, this train appears to move with the sum of the velocities of the two trains. Thus, if one train be moved at twenty miles an hour, while the other is moved at twenty-five miles an hour, the apparent motion of the passing train will be the same as would be the motion of a train moved at forty-five miles an hour passing a train at rest.

89. If the line joining a visible object with the eye be moved at both its extremities in the same direction, which would be the case if the observer and the object were carried in parallel lines, then the change of direction which the line of motion would undergo would arise from the difference of the velocities of the observer and of the object seen.

If the observer in this case moved slower than the object, the extremity of the line of motion connected with the object would be carried forward faster than the extremity connected with the observer, and the object would appear to move in the direction of the observer's motion, with a velocity equal to the difference; but if, on the contrary, the velocity of the observer were greater than that of the object, the extremity of the line connected with the observer would be carried forward faster than that connected with the object, and the change of direction would be the same as if the object were moved in a contrary direction with the difference of the velocities.

It is easy to perceive that a vast variety of complicated relations which may exist between the directions and motions of the observer and of the object observed, will give rise to very complicated phenomena of apparent motion. Thus, relations may be imagined between the motion of the observer and that of the object perceived by which, though both are in motion, the object will appear stationary; the motion of the one affecting the line of direction in an equal and contrary manner to that with which it is affected by the other; and, in the same manner, either motion may prevail over the other more or less, so as to give the line of direction a motion in accordance with or contrary to the real motion of the object.

90. All these complicated phenomena of vision are presented in the problems which arise on the deduction of the real motion of the bodies composing the solar system from their apparent motions. The observer placed in the middle of this system is transported upon the earth in virtue of its annual motion round the sun with a prodigious velocity, the direction of his motion changing from day to day according to the curvature of the orbit. The bodies which he observes are also affected with various motions at various distances around the sun, the combination of which with the motion of the earth gives rise to complicated phenomena, the analysis of which is made upon the principles here explained.

91. It is usual to express the relative position in which objects are seen by the relative direction of lines drawn to them from the eye; and the angle contained by any two such lines is called the angular or visual distance between the objects. Thus, the angular distance between the objects A and B, fig. 14, is expressed by the magnitude of the angle A E B. If this angle be 30°, the objects are said to be 30° asunder. It is evident from this that all objects which lie in the direction of the same lines will be at the same angular distance asunder, however different their real distance from each other may be. Thus, the angular distance between A and B, fig. 14, is the same as the angular distance between A′ and B′.

PERCEPTION OF BULK AND FORM.

92. Sight does not afford any immediate perception either of the volume or shape of an object. The information which we derive from the sense, of the bulk or figure of distant objects, is obtained by the comparison of different impressions made upon the sense of sight by the same object at different times and in different positions. A body of the spherical form seen at a distance appears to the eye as a flat circular disk, and would never be known to have any other form, unless the impression made upon the eye were combined with other knowledge, derived from other impressions through sight or touch, or both these senses, and thus supplied the understanding with data from which the real figure of the object could be inferred. The sun appears to the eye as a flat, circular disk; but, by comparing observations made upon it at different times, it is ascertained that it revolves round one of its diameters in a certain time, presenting itself under aspects infinitely varying to the observer; and this fact, combined with its invariable appearance as a circular disk, proves it to be a sphere; for no body except a sphere, viewed in every direction, would appear circular.

Although we do not obtain from the sense of sight a perception of the shape of a body, we may obtain a perception of the shape of one of its sections. Thus, if a section of the body be made by a plane passing through it at right angles to the line of vision, the sight supplies a distinct perception of the shape of such section. Thus, if an egg were presented to the eye with its length in the direction of the line of vision, it would appear circular, because a section of it made by a plane at right angles to its length is a circle; but if it were presented to the eye with its length at right angles to the line of vision, it would appear oval, that being the shape of a section made by a plane passing through its length.

If a body, therefore, presents itself successively to the eye in several different positions, we obtain a knowledge by the sense of sight of so many different sections of it, and the combination of these sections may in many cases supply the reason with data by which the exact figure of the body may be known.

93. As the term "apparent magnitude" is used to express the visual angle under which an object is seen, we shall adopt the term *visible area* to express the apparent magnitude of the section of a visible object made by a plane at right angles to the line of vision, that is to say, to the line drawn from the eye to the centre of the object.

94. Besides receiving through the sight a perception of the figure of the section of the object which forms its visible area, we also obtain a perception of the lights and shades and the various tints of colour which mark and characterise such area. By

comparing the perception derived from the sense of touch with those lights and shades, we are enabled by experience and long habit to judge of the figure of the object from these lights and shades and tints of colour. It is true that we are not conscious of this act of the understanding in inferring shape from colour and from light and shade; but the act is nevertheless performed by the mind. The first experience of inference is the comparison of the impressions of sight with the impressions of touch; and one of the earliest acts of the mind is the inference of the one from the other. It is the character of all mental acts, that their frequent performance produces an unconsciousness of them; and hence it is that when we look at a cube or a sphere of a uniform colour, although the impression upon the sense of sight is that of a flat plane variously shaded, and having a certain outline, the mind instantly substitutes the thing signified for the sign, the cause for the effect; and the conclusion of the judgment, that the object before us is a sphere or a cube of uniform colour, and not as it appears, a flat plane variously shaded, is so instantaneous, that the act of the mind passes unobserved.

The whole art of the painter consists in an intimate practical knowledge of the relation between these two effects of perception of sight and touch. The more accurately he is able to delineate upon a flat surface those varieties of light and shade which visible objects immediately produce upon the sense, the more exact will be his delineation, and the greater the *vraisemblance* of his picture.

What is called relief in painting is nothing more than the exact representation on a flat surface of the varieties of light and shade produced by a body of determinate figure upon the eye; and it is accordingly found that the flat surface variously shaded produced by the art of the painter has upon the eye exactly the same effect as the object itself, which is in reality so different from the coloured canvas which represents it.

95. The immediate impressions received from the sense of sight are those of light and colour. The impressions of distance, magnitude, form, and motion are the mixed results of the sense of sight and the experience of touch. Even the power of distinguishing colours is not obtained immediately by vision without some cultivation of this sense. The unpractised eye of the new-born infant obtains a general perception of light; and it is certain that the power of distinguishing colours is only found after the organ has been more or less exercised by the varied impressions produced by different lights upon it. It would not be easy to obtain a summary demonstration of this proposition from the experience of infancy, but sufficient evidence to establish it is supplied by

the cases in which sight has been suddenly restored to adults blind from their birth. In these cases, the first impression produced by vision is that the objects seen are in immediate contact with the eye. It is not until the hand is stretched forth to ascertain the absence of the objects seen from the space before the eye that this optical fallacy is dissipated.

The eye which has recently gained the power of vision at first cannot distinguish one colour from another, and it is not until time has been given for experience, that either colour or outline is perceived.

96. Besides that imperfection incident to the organs of sight arising from the excess or deficiency of their refractive powers, there is another class which appear to depend upon the quality of the humours through which the light proceeding from visible objects passes before attaining the retina. It is evident that if these humours be not absolutely transparent and colourless, the image on the retina, though it may correspond in form and outline with the object, will not correspond in colour; for if the humours be not colourless, some constituents of the light proceeding from the object will be intercepted before reaching the retina, and the picture on the retina will accordingly be deprived of the colours thus intercepted. If, for example, the humours of the eye were so constituted as to intercept all the red and orange rays of white light, white paper, or any other white object, such as the sun, for example, would appear of a bluish-green colour; and if, on the other hand, the humours were so constituted as to intercept the blues and violets of white light, all white objects would appear to have a reddish hue. Such defects in the humours of the eye are fortunately rare, but not unprecedented.

97. Sir David Brewster, who has curiously examined and collected together cases of this kind, gives the following examples of these defects:—

A singular affection of the retina in reference to colour is shown in the inability of some eyes to distinguish certain colours of the spectrum. The persons who experience this defect have their eyes generally in a sound state, and are capable of performing all the most delicate functions of vision. Mr. Harris, a shoemaker at Allonby, was unable from his infancy to distinguish the cherries of a cherry-tree from its leaves, in so far as colour was concerned. Two of his brothers were equally defective in this respect, and always mistook orange for grass-green, and light green for yellow. Harris himself could only distinguish black and white. Mr. Scott, who describes his own case in the Philosophical Transactions, mistook pink for a pale blue, and a full red for a full green.

All kinds of yellows and blues, except sky-blue, he could discern with great nicety. His father, his maternal uncle, one of his sisters and her two sons, had all the same defect.

A tailor at Plymouth, whose case is described by Mr. Harvey, regarded the solar spectrum as consisting only of yellow and light blue; and he could distinguish with certainty only yellow, white, and green. He regarded indigo and Prussian blue as black.

Mr. R. Tucker described the colours of the spectrum as follows :—

Red mistaken for	brown.
Orange ,,	green.
Yellow sometimes	orange.
Green ,,	orange.
Blue ,,	pink.
Indigo ,,	purple.
Violet ,,	purple.

A gentleman in the prime of life, whose case I had occasion to examine, saw only two colours in the spectrum, viz. yellow and blue. When the middle of the red space was absorbed by a blue glass, he saw the black space with what he called the yellow on each side of it. This defect in the perception of colour was experienced by the late Mr. Dugald Stewart, who could not perceive any difference in the colour of the scarlet fruit of the Siberian crab, and that of its leaves. Dr. Dalton was unable to distinguish blue from pink by daylight; and in the solar spectrum the red was scarcely visible, the rest of it appearing to consist of two colours. Mr. Troughton had the same defect, and was capable of fully appreciating only blue and yellow colours; and when he named colours, the names of blue and yellow corresponded to the more and less refrangible rays; all those which belong to the former exciting the sensation of blueness, and those which belong to the latter the sensation of yellowness.

In almost all these cases, the different prismatic colours had the power of exciting the sensation of light, and giving a distinct vision of objects, excepting in the case of Dr. Dalton, who was said to be scarcely able to see the red extremity of the spectrum.

Dr. Dalton endeavoured to explain this peculiarity of vision by supposing that in his own case the vitreous humour was blue, and therefore absorbed a great portion of the red and other least refrangible rays; but this opinion is, we think, not well founded. Sir J. Herschell attributes this state of vision to a defect in the sensorium, by which it is rendered incapable of appreciating exactly those differences between rays on which their colour depends.

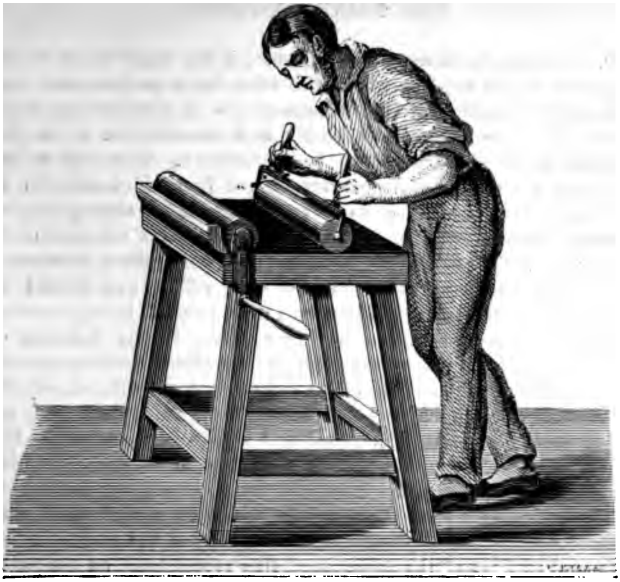


Fig. 2.

THE PRINTING PRESS.

CHAPTER I.

1. The improvement of the art not promoted by men of letters and science.—2. General signification of printing.—3. Printing by models in relief.—4. Method of engraving the block.—5. Antiquity of this art.—6. Invention of movable type.—7. Use of movable types for printing successive books or parts of a book.—8. Process of printing.—9. Composition.—10. Quadrats.—11. Use of the chase.—12. Imposing.—13. Reading and correcting.—14. Successive operations in printing.—15. Inking.—16. Inking-rollers.—17. Stanhope press.—18. Printing-machines.—19. General description of them.—20. Single printing-machines.—21. Double printing-machines.—22. Perspective view and description of Applegath and Cowper's double printing-machine.

1. It is a remarkable fact, that printing, which has so far transcended all other arts in the influence it has exerted in the advancement of knowledge and the progress of the human race, owes almost nothing to the class devoted professionally to letters and the sciences, and on whom it has, nevertheless, bestowed the largest measure of advantage.

2. Printing, in its most general sense, is the name given to all processes in the arts, by which the same forms or characters are indefinitely multiplied, by the impressions of the surface upon which they are formed repeatedly and successively, upon the surface to which they are to be transferred. Thus, in calico printing, the same figures are transferred in rapid succession to different pieces of cloth, or to different parts of the same piece, by means of blocks or rollers, upon which the figures are produced, either in *relief* or *intaglio*, that is, either in raised or sunken characters. In such cases the blocks, or rollers, are pressed in succession on the surface of the cloth to be printed, being however previously smeared with colouring matter. In the printing of copper or steel engravings, the design is produced by the engraver in lines sunk in the surface of the copper or steel by the engraving tool. These lines being filled with the printing-ink, and all other parts being carefully cleaned, the plate is impressed on the paper with an intense pressure by means of a press specially adapted to that purpose. The paper being previously moistened, absorbs the ink from the lines in which it is deposited, and exhibits after the impression a perfect copy of the engraving,—the sunken lines of the engraving being represented on the paper by corresponding lines in ink.

3. In wood-engravings, and in ordinary book-printing, the original from which the impressions are taken is in relief. A model in relief of the page to be printed is formed in metal called *type-metal*, consisting of lead rendered hard by being alloyed with a small proportion of antimony. The surface being smeared with the colouring-matter called *printing-ink*, is impressed upon the paper, and a *fac-simile* of the original relief is thus produced.

4. In the earliest and rudest attempts at printing, a manuscript page was attached to the surface of a block of wood, which was carved into relief corresponding with the characters of the manuscript. The impression produced by this means was necessarily a *fac-simile*, more or less accurate, of the manuscript itself.

5. The method of printing by means of blocks of wood, or metal, carved in relief, is the earliest example on record of the practical use of the art which, in its more improved state, has exercised so important an influence upon civilisation. According to some antiquarian authorities, the art of producing characters in this way may be traced as far back as the building of Babylon. The characters found upon bricks, taken from the supposed site of that city, having been undoubtedly printed by the method here described. We are in possession of metal stamps, with words engraved in relief, which the Romans made use of to mark their

various articles. If the modern art of making paper had been known in those remote times, it is very probable that the art of printing books would have existed at a much earlier date than that of its actual commencement, for with the same kind of stamps precisely, as those by which the Roman tradesmen marked their wares, books might have been printed, and the same engravings which adorned the shields and pateras of ancient times might, by the aid of paper, have spread the intelligence of Greece and Italy over the world.

According to Du Halde and certain missionaries, the art of printing from blocks carved in relief was practised in China fifty years before the Christian era; and, from the early commercial intercourse of the Venetians with that country, there is reason to believe that the knowledge of this art, in its application to the multiplying of books, was originally derived from thence, for Venice is the first place in Europe in which it is recorded to have been practised.

Its first application was to the production of playing cards and religious prints, and when the art was first extended to books they were printed by carving each page upon a separate block. This process of carving the characters in relief, which was probably executed by attaching the manuscript to the face of the block and engraving from the manuscript, will afford an easy and obvious explanation of the diversity of characters found in ancient books printed from such blocks, and will explain the great similarity which exists between books thus printed and manuscripts. This similarity was increased by their being printed on one side of the paper only, the indentation produced by the impression being removed by burnishing the back. Two leaves were then pasted together, making such a perfect *fac-simile* of the manuscript, as to require, even at the present day, great discrimination and much chemical skill to distinguish such books from real manuscripts; and as they have no printers' names, dates, or places affixed to them, it is impossible to ascertain by whom, or when, or where they were executed. The fabrication of these pseudo-manuscripts involved the first introduction of the art of printing.

6. **Movable Types.**—About the middle of the fifteenth century the art of printing in this rude manner acquired considerable extension; but as each separate work required to have separate blocks for each page, and since the blocks for one work were altogether useless for another, the printers soon began to feel the inconvenience arising from the storage of such numerous collections of blocks, to say nothing of the expense of carving them. They were, therefore, stimulated to seek for some method less costly and cumbrous, by which the models in relief of the pages could be

produced, and so that the materials of the model of any one page might be afterwards useful, in the formation of the models of other pages. The discovery of the means of accomplishing this object by movable types constitutes the most important epoch in the history of printing, and is sometimes even regarded, in all essential respects, as the invention of printing itself. After it had undergone some successive improvements, it resolved itself into the production of models in relief of the letters of the alphabet, formed upon the extremities of small bars of metal, which being properly selected and placed in juxtaposition, formed the words and letters of a page. Such are the *types* of the modern printer.

The honour of the invention of movable types has been disputed by two cities, Haarlem and Mentz. The claims of Haarlem rest chiefly upon a statement of Hadrien Junius, who gave it upon the testimony of Cornelius, alleged to be a servant of Lawrence Coster, for whom the invention is claimed. The claims of Mentz, which appear to be more conclusive, are in favour of Peter Schæffer, the assistant and son-in-law of John Faust, better known as Dr. Faustus. The first edition of the *Speculum humanæ salvationis* was printed by Coster at Haarlem, about the year 1440, and is one of the earliest productions of the press of which the printer is known. The celebrated Bible, commonly known as the Mentz Bible, without date, is the first important specimen of printing with movable metal types. This was executed by Gutenberg and Faust, or Fust, as it is sometimes spelt, between the years 1450 and 1455. The secret of the method then becoming known, presses were speedily established in all parts of Europe, so that before the year 1500 there were printing-offices in upwards of 220 different places in Austria, Bavaria, Bohemia, Calabria, the Cremonese, Denmark, England, Flanders, France, Franconia, Frioul, Geneva, Genoa, Germany, Holland, Hungary, Italy, Lombardy, Mecklenberg, Moravia, Naples, the Palatinate, Piedmont, Poland, Portugal, Rome, Sardinia, Upper and Lower Saxony, Sicily, Silesia, Spain, Suabia, Switzerland, Thessalonica, Turkey, Tuscany, the Tyrol, Venice, Verona, Westphalia, Wurtemberg, &c.

This vast and rapid extension of the art, combined with the skill which the earlier printers displayed in it, seems to be totally incompatible with the date assigned to the invention, and it is more probable, that the art having been long practised in private under continued attempts at secrecy, it at length broke into publicity after it had already attained a considerable degree of perfection.

7. When the page of a book is formed by properly combining

the types, and a sufficient number of copies of it produced by the process of printing, the types which form it are disengaged and separated and used to form other pages of the same or other books. Thus, while in the first attempts at printing, each model of letter in relief never did any other duty than the printing of the very book for which it was formed, the type of each letter in printing with movable types is transferred from page to page, and is used successively in the printing of an indefinite number of pages of the same or different works.

8. **The process of printing,** then, consists in a certain succession of operations, the first of which is putting together the types so as to form lines and pages; the second, putting together these pages in such a manner, that when impressed upon sheets, and the sheets folded, they will succeed each other in the proper order. The subsequent operations of folding, stitching, and combining these sheets together, so as to form a volume, is the business of the bookbinder.

9. **Composition.**—The process of putting the types together is called *composing*, and the person who performs this operation is called a *compositor*. He stands before an inclined desk, as shown in the view of the composing-room (fig. 1), which is divided into a number of compartments of different sizes, A, B, in each of which are placed a certain number of types of a particular letter. By practice he learns without hesitation to direct his hand to the compartment which contains the letter he wants, without removing his eye from the manuscript which lies before him. He holds in his left hand an instrument called a *composing-stick*, which is so formed as to receive the types in successive juxtaposition, until the requisite number have been placed to form a complete line, after which another line is composed in like manner, and thus line after line is composed until a complete page has been formed. The spaces between words are made by the insertion of small bars called *quadrats*, similar to those of type, but having no letter cast upon their ends, and the spaces between line and line are produced by the insertion of thin plates of metal called *leads*. When the lines are considerably separated from one another, they are accordingly said to be "leaded." When a page has been composed the compositor ties a cord round it, called a *page-cord*, to hold the types of which it consists provisionally together, and placing it apart, proceeds to form another page, and so on.

10. Since every line of the same page must necessarily have the same length, whether the types which compose it fill out that length or not, any deficient space is filled by quadrats placed at the most convenient points between the words.

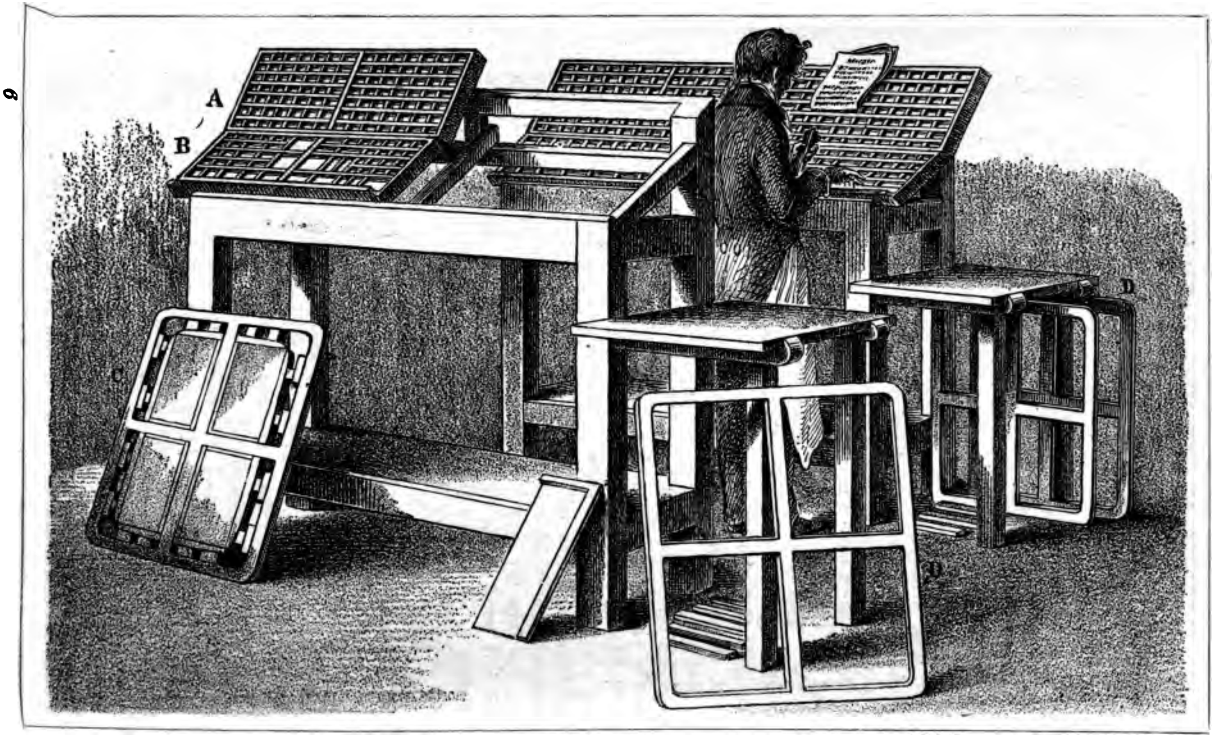


Fig. 1.—Composing Room.

In like manner the blank parts of last lines of paragraphs are filled with quadrats.

11. When the pages of one side of a sheet have been thus composed, they are placed in the divisions of an iron form called a *chase*, C, D, several of which appear in the view of the composing-room, fig. 1. These chases, of course, vary in their form and mode of division according to the size and number of the pages which form a sheet. We have here supposed the pages which are composed and arranged in the chase to be those which are required to be printed on one side of the sheet. A similar number are composed and similarly put together in another chase, being those to be printed on the other side of the sheet.

12. **Imposing.**—The process of arranging the pages in the chase is called "imposing."

13. **Readers and Correctors.**—When the pages composing each side of the same sheet have been thus "*imposed*," and the types securely fastened in the chase by proper wedges, the chases are brought to a printing-press, which will be presently described, where a single impression is taken from them, called the *first proof*, which, being properly folded, is taken to a person called the "*reader*," who has always a boy capable of reading the manuscript to assist him. While the boy reads the manuscript, the "*reader*" follows him upon the proof, which he carefully examines, and upon which he marks the errors of the compositor. The proof is then returned to the compositor, who corrects the errors indicated by the reader, and a second impression is then taken with more care, and generally on better paper. This is called a *clean proof*, and is again examined by the reader to ascertain whether the compositor has corrected all the errors previously indicated; and if there are none uncorrected, the proof is then sent to the author. In good printing-offices there are few or no press errors found in the author's proof, those corrected by him being in general errors which had been overlooked in his own manuscript, or corrections of language suggested to him in the revision of the sheet.

14. After the sheet has received the correction of the author, the form to be printed is laid upon a horizontal table, with the faces of the types uppermost, and the following operations are executed:—1st. Printing-ink is applied to the faces of the type, so evenly that there shall be no blotting or inequalities in the printing; 2nd. The sheet of paper to be printed is laid upon the form so as to receive the impression of the type in its proper position, and in the centre of it; 3rd. This paper is urged upon the type by a sufficient pressure to enable it to receive the printed characters, such pressure, however, not being so great as to cause

the type to penetrate or deface the paper; 4th. The paper is, in fine, when thus printed, withdrawn from the type and laid upon a table, where the printed sheets are collected.

15. **Inking.**—In the old process these operations were performed by two men, one of whom was employed to ink the types, and the other to print. The former was armed with two bulky inking-balls, consisting of a soft black substance of leathery appearance, spherical form, and about twelve inches in diameter. He flourished these with dexterity, dabbed them upon a plate smeared with ink, and then with both hands applied them to the faces of the types until the latter were completely charged with ink. This accomplished, the other functionary—the pressman—having prepared the sheet of paper while the type was being inked, turned it down upon the type, drew it under the press, and with a severe pull of the lever gave the necessary pressure by which the paper took the impression of the type. A contrary motion of the apparatus withdrew the type from under the press, and the pressman, removing the paper now printed, deposited it upon a table placed near him to receive it. The same series of operations was then repeated for producing the impression of another sheet and so on. In this manner two men in ordinary book-work usually printed at the rate of 250 sheets per hour on one side.

16. **Inking-rollers.**—One of the first improvements which took place upon this apparatus consisted in the substitution of a cylindrical roller for the inking-balls. This roller was mounted with handles, so that the man employed to ink the type first rolled it upon a flat surface smeared with ink (fig. 2), and having thus charged it, applied it to the type form, upon which he rolled it in a similar manner, thus transferring the ink from the roller to the faces of the type. The substitution of these inking-rollers for the inking-balls constituted one of the most important steps in the modern improvement of the art of printing. The rollers were composed of a combination of treacle and glue, and closely resembled caoutchouc in their appearance and qualities.

17. **Stanhope Press.**—The process by which these operations were executed, assumed in the course of years a great variety of improved forms, and one of the most celebrated and most universally adopted having been supplied by the inventive genius of Earl Stanhope, has accordingly retained his name, and is known as the *Stanhope press*. This machine, which, resembling all other improved presses in its general features, and serving, therefore, as an example of hand-presses in general, is shown in fig. 3. The two principal parts of the machine are *first*, that which produces the pressure, and the *second*, that which supports the paper.

The former is a massive frame of cast iron, formed in a single

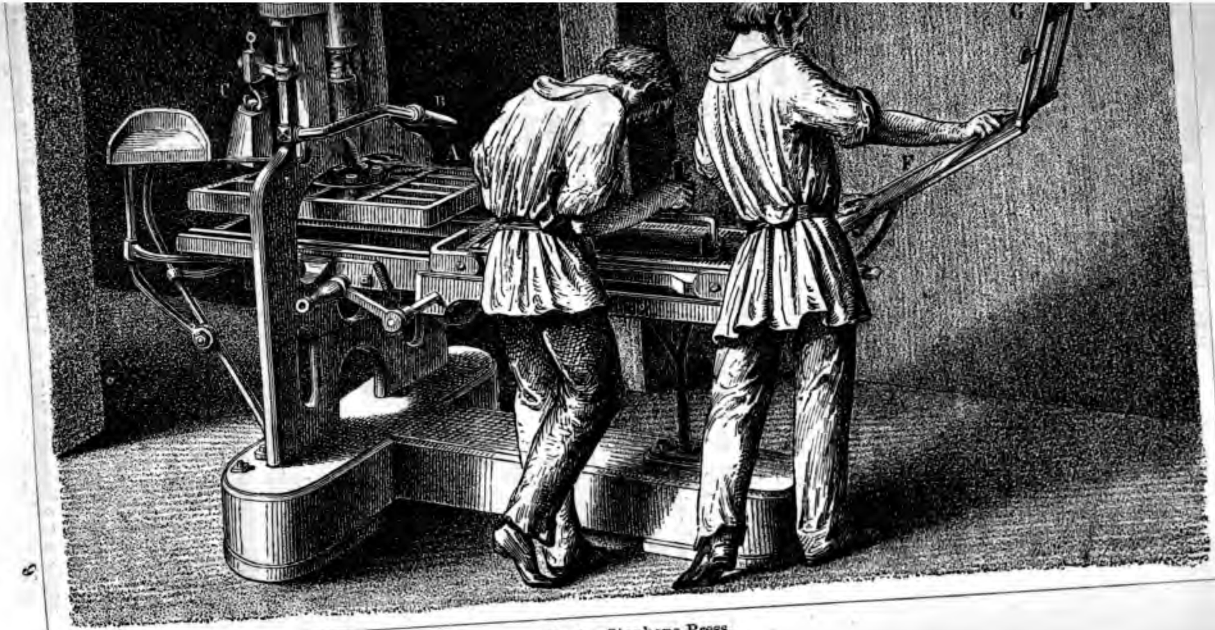
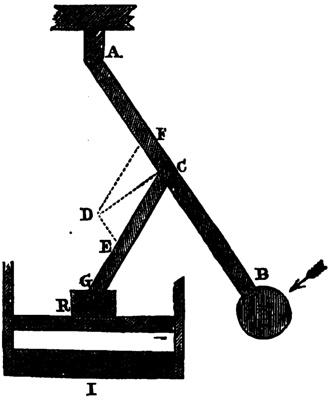


Fig. 3.—Stanhope Press.

piece, in the upper part of which is a nut, in which a screw moves—the point of which acts upon the upper end of a slider, which is fixed into a dovetailed groove formed between two vertical bars of the frame. This slider has attached to its lower end a square plate, called the *platten*, which rises and falls according as the screw is turned in the one direction or the other. The weight of the platten fig. 3, A, and slider, which is considerable, is counterpoised by a heavy weight C suspended by a lever behind the press. The flat table, called the *carriage*, upon which the form of types is laid, is moved backwards and forwards by means of a winch, which appears in fig. 3. By means of this winch, and the rack or band with which it is connected, the carriage with the type form can be moved by the pressman alternately backwards and forwards, so that it can be brought under the platten, and after having received the pressure, can be removed back to its first position. The platten is made to impart the pressure by means of a lever called the *knee lever*, an expedient which is much used in the arts in cases where any intense pressure is required to be produced through a very limited space. The mechanical effect of this species of lever will be understood by a reference to fig. 4, where A B is a metal rod, having a fixed point of support A on which it works; another bar G C is jointed to it at C, a point intermediate between A and B. This bar C G is jointed at G to a plate such as R, or any other object to which it is desired to transmit any intense force acting through a very limited space, as, for example, in the present case, where the paper is pressed upon the type by a plate which is driven upon it by a sudden and severe force. The handle B of the lever being pressed in the direction of the arrow, exerts a corresponding pressure on the point C, which is driven in the direction C D perpendicular to A B. This motion C D is resolved into two by the parallelogram of forces, one in the direction C E, and the other in the direction C F; the latter exerts pressure on the fixed point A, and the other acts upon the plate R by means of the joint G forcing it downwards. As the joint C advances, the *angle* A C G becomes more and more obtuse, and the component C E

Fig. 4.



of the force acting at B, bears a rapidly increasing proportion to the force itself, so that when the levers A C and C G come nearly into a right line, the pressure exerted at B is augmented at G in an almost infinite proportion.

In working the press, the pressman places a sheet of paper to be printed upon the frame F, called the *tympan*, where it is held in its place by turning over it the frame G, which is supplied with rods or cords corresponding to the spaces between the pages of the form. While the pressman is thus employed, his assistant is engaged in inking the types with a roller, as shown in fig. 3. When this has been accomplished, the pressman turns down the tympan carrying the paper upon the types, and then, by turning the handle, moves the carriage with the type form upon it under the platten, and applying his hand to the handle above him presses the platten down upon the tympan carrying the paper, and by means of the knee lever produces a sudden and severe pressure by which the paper receives the impression of the type. The handle is then moved in a contrary direction, the platten being raised from the type form, and by turning the other handle the carriage with the type form is removed from under the platten. The pressman then raises the tympan from the types, and taking the printed sheet off, replaces it by a fresh blank sheet, over which he turns the frame as before; and while he is performing this operation, his assistant is occupied in inking the types, after which the same operations are performed, and another sheet is printed, and so on.

18. **Printing Machines.**—The printing presses which served the purposes of publication for some hundred years, during which they received no other improvements than such as might be regarded merely as modifications in the detail of their mechanism, have been almost entirely superseded by engines of vastly increased power and improved principles of construction. Although these admirable machines differ one from another in the details of their mechanism, according to the circumstances under which they are applied, and the power they are expected to exert, they are nevertheless characterised by certain common features.

19. The form to be printed is laid in the usual manner upon a perfectly horizontal table, with the faces of the types uppermost; and upon the same table, in juxtaposition with the form, and level with the faces of the types, or nearly so, is placed a slab upon which a thin and perfectly regular stratum of printing-ink is diffused; the table thus carrying the form and inking-slab is moved by proper machinery right and left horizontally, with a reciprocating rectilinear motion through a space a little greater than the length of the form.

Above the form and slab are mounted, also in juxtaposition, a large cylinder or drum, which carries upon it the sheet of paper to be printed, and three or four inking-rollers similar to that already described. There are also three or four other rollers in juxtaposition with the latter, one of which supplies ink to the others, which severally spread it in a uniform stratum upon the slab. The paper-cylinder and the inking and diffusing rollers are so mounted, that when the horizontal table, carrying the form and inking slab, moves alternately backwards and forwards under them, they roll upon it.

In this way, when the table is moved towards the rollers, the form, passing under the inking-rollers right and left, receives from them the ink upon the face of the type; and at the same time the slab, moving backwards and forwards under the diffusing rollers, receives from them, upon its surface, the proper stratum of ink to supply the place of that which was taken from it by the inking-rollers.

20. **Single Printing Machines.**—When the table is moved alternately towards the other side, the form, with the types already inked, passes under the cylinder carrying the paper, the motion of which is so regulated as to correspond exactly with the rectilinear motion of the table carrying the form. The cylinder is urged upon the type with a regulated force, sufficient and not more than sufficient, to impress the type upon the paper.

The sheets of paper are supplied in succession to the cylinder, and held evenly upon it by bands of tape while they pass in contact with the type. After receiving the impression of the type, the tapes which bound them are separated, and the printed sheets discharged.

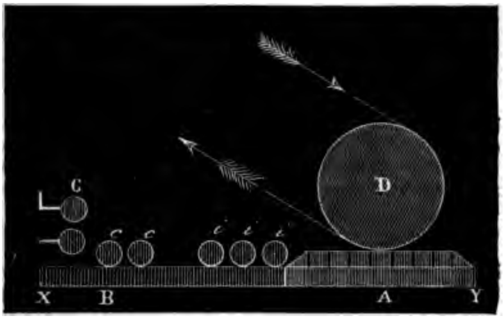
Such is the general principle of single printing-machines.

21. **Double Printing Machines.**—In these the table which is moved alternately right and left, carries two forms, one corresponding to the pages to be printed on one side of the sheet, and the other to those to be printed on the other side. There are also two inking-slabs, one to the left of the left-hand form, and the other to the right of the right-hand form. There are also two paper cylinders, and two sets of inking and diffusing-rollers. Each sheet of paper to be printed, being held between tapes, as already described, is carried successively round the two cylinders, being so conducted, in passing from one to the other, that one side of it passes in contact with, and is printed by, one form, and the opposite side by the other form. The proportion of the motions is so nicely regulated, that the impression of each page or column made on one side of the paper, corresponds exactly with *that of* the corresponding page or column on the other side.

This general description will be more clearly understood by reference to the following illustrative diagrams :—

Fig. 5 illustrates the operation of a single printing-machine. The form A and the inking-slab B, are placed on a horizontal table ; above them is the paper-cylinder D, the inking-rollers *i i i*, the diffusing-rollers *c c*, and the rollers C, which supply the ink to the diffusing-rollers. The first of these, C, is called the ductor roller. When the table X Y is moved towards the left, from Y to X, the form A passes under the inking-rollers *i i i*, and receives ink from them on the faces of the type ; at the same time the slab B passes under the diffusing-rollers *c c*, and receives from them a supply of ink to replace what it has just given to the inking-rollers.

Fig. 5.



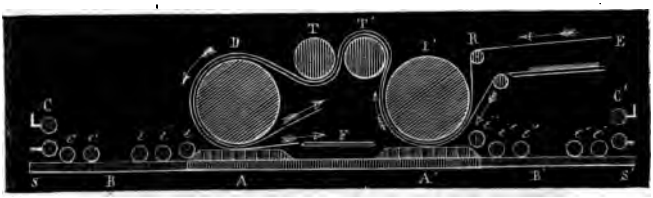
When the table is moved in the contrary direction, from X towards Y, the form once more passes under the inking-rollers, and afterwards under the paper-cylinder, which being pressed upon it, while it moves in exact accordance with it, the types discharge upon the paper the ink they have just received from the rollers ; and the printing of the paper being thus effected on one side, the sheet is discharged from the tapes. The table is then again moved to the left, and the types are again inked, and the same effects ensue as have already been described.

In this manner sheet after sheet is printed.

The inking and diffusing-rollers rest upon the slab and types by their weight, the axes projecting from their ends being inserted in slits formed in upright supports, attached to opposite sides of the frame which supports the moving table. The two upright pieces in which the axes of each roller are inserted, are not placed in exact opposition to each other ; the consequence of which is, that the rollers are placed with their axes slightly inclined to the sides of the table. This arrangement is attended with a very important effect : for, in consequence of the friction or adhesion of the rollers with the slab, they are moved alternately in contrary directions with the longitudinal motion across the table. This motion, combined with their rolling motion upon the slab, aids materially in diffusing the ink in a perfectly uniform stratum.

An illustrative diagram of a double printing-machine is shown in fig. 6, where D and D′ are the two paper-cylinders; A and A′, the two forms; *i i i* and *i′ i′ i′*, the inking-rollers; *c c* and *c′ c′*, the diffusing-rollers; and C and C′ the ductor-rollers. The pile of paper placed on the table E, is supplied sheet by sheet to the tapes between which it is held; and being passed over the roller R, and under the cylinder D′, it receives the impression of the types of the form A′; it then passes successively over the roller T′, under T, and round the cylinder D, at the lower point of which its unprinted side comes into contact with the types of the form A, by which it is printed; after which, the tapes opening, it is thrown out by the centrifugal force upon the receiving table F.

Fig. 6.



It will be apparent by the figure, that while the sheet is printed on one side by the form A′, the form A is passing between the inking-rollers *i i i*, and the slab B; and on the contrary, while the paper is printed on the other side by the form A, the form A′ is passing between the inking-rollers *i′ i′ i′* and the slab B′.

In this manner, by each alternate motion from right to left, and from left to right, a sheet is printed on both sides.

22. A perspective view of a double-acting printing machine, as constructed by Messrs. Applegath and Cowper, is shown in fig. 7.

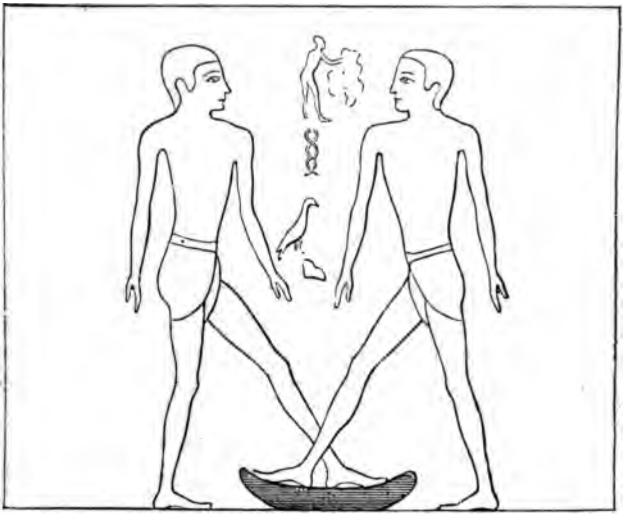
A boy, called the *layer-on*, E, standing at an elevated desk, pushes the paper, sheet by sheet, towards the tapes, which, closing upon it, carry it over a roller R, passing under which it is carried to the right of the cylinder D, under which it passes, and being carried up to the left of it, passes successively over the roller T, under the roller T′, over the cylinder D, and drawn along its left side, after which it passes under it, and is flung into the hands of a boy, F, called the *taker-off*, seated before a table placed between the two cylinders D and D′, upon which he disposes the sheets as he receives them.

In this manner the layer-on feeds the machine in constant succession with blank sheets, which, being carried under the cylinder D, are printed on one side, and afterwards under the cylinder D′, are printed on the other, when they are received by the taker-off.

ANCIENT POTTERY.

"No, let a pot be formed, of amplest size,
Within whose slender sides the fish, dread sire,
May spread his vast circumference entire!
Bring, bring the tempered clay, and let it feel
The quick gyrations of the plastic wheel:
But, Cæsar, thus forewarned, make no campaign,
Unless your potters follow in your train."—GIFFORD.

Fig. 1.



5. In the catacombs of Thebes and Beni-Hassan, which have been proved to have existed nineteen centuries before Christ, and therefore 3700 to 3800 years from the present time, drawings have been discovered, exhibiting, in a great variety of forms, the processes of the potter's art as then practised. The annexed engravings (fig. 1 to 5) have been copied from paintings discovered in the catacombs of Thebes, and described by Champollion. They exhibit the processes of the potter, from the kneading of the dough by the feet to the removal of the baked article from the oven.

6. Fig. 1 represents two potters kneading the paste by the process of treading. The hieroglyphics signify "he treads."

Fig. 2.—A man taking up the dough to form it into a mass for the wheel. The hieroglyphics express this action.

Fig. 3.—The same man taking the ball, or prepared mass, to the potter who works at the wheel.

The ductor-rollers, C and C′, are kept in revolution by endless bands, carried over rollers at the lower parts of the frame, and then over grooved wheels fixed on the axes of the cylinders. The table carrying the forms and slabs is moved alternately right and left by means of a pair of bevelled wheels, W, under the frame, and a double rack and pinion above; one of the bevelled wheels, having a horizontal axis, receives motion from a steam-engine or other moving power; it imparts motion to the other bevelled wheel, having a vertical axis. This latter axis has a pinion fixed at its upper end, which works in a double rack attached to the movable type-table, which is so constructed that the continuous rotation of the pinion imparts an alternate rectilinear motion right and left to the rack and to the table attached to it.

The manner in which the tapes lay hold of and conduct the paper successively round the cylinders, and finally discharge it upon the table of the taker-off, will be easily understood by reference to fig. 8, page 177.

C and D are two grooved rollers, surrounded by an endless band which pushes the paper from the table of the layer on towards the tapes. The two endless tapes, between which the paper is held, are represented in the diagram by the continuous and dotted lines, and the direction of their motion round the rollers and cylinders is represented by the arrows. It will be perceived that opposite the table of the layer-on, the tapes converge, from two small rollers *d* and *h*, and come into contact at the top of the roller E. The edges of the sheets of paper, being advanced from the table of the layer-on, are caught between the tapes immediately above the roller E.

It must be understood that there are two or three pairs of tapes parallel to each other, which correspond to the margins of the pages or columns; but only one pair is shown in the figure.

The paper being thus seized between the tapes above the roller E, is carried successively, as shown in the figure, still held between the tapes, under and over F H I and G, until it arrives at *i*, where the tapes separate, that which is indicated by the continuous line being carried to the roller *a*, and that by the dotted line, over the roller *i*, to the roller *k*. The tapes being thus separated the printed sheet is discharged at *i*, upon the table of the taker-off; meanwhile, the tape indicated by the continuous line is carried successively over the roller *a*, under *b*, under *c*, outside *d*, and is finally returned to the roller E.

In the same manner the tape indicated by the dotted line is carried successively under the roller *k* and *m*, outside *n*, over *v* and *h*, from which it returns to E, where it again joins the other tape proceeding from *d*.

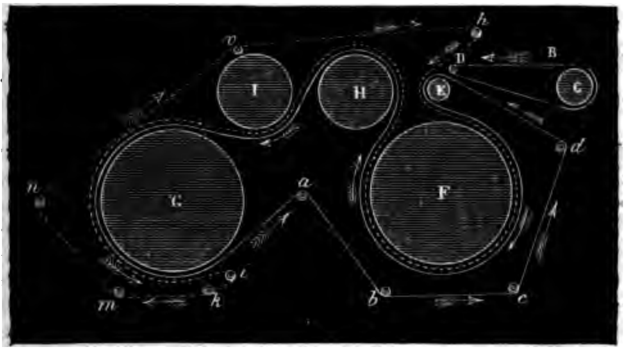


Fig 8.

THE PRINTING PRESS.

CHAPTER II.

23. Machine of *The Times* of 1814. — 24. Improvement of this. — 25. Present printing machine of *The Times*. — 26. Marinoni's newspaper printing machine.—27. Marinoni's book-printing machine.—28. Newspapers.—29. Reporters.—30. Court newsman.—31. Foreign correspondent.—32. Newspaper statistics.

23. The first machines constructed upon this improved principle for printing newspapers, were erected at the printing office of *The Times* newspaper, and it was announced in that journal, on the 28th of November, 1814, that the sheet which was then placed in the hands of the reader, was the first printed by steam-impelled machinery.

By this, with some improvements which the apparatus received soon afterwards, the effective power of the printing-press was augmented in a very high proportion. With the hand-presses previously in use, not more, as we have seen, than 250 sheets could be printed on one side in an hour. Each of the two machines erected at *The Times* office produced 1800 impressions per hour.

24. **Further Improvement.**—The power of the printing-machine constructed upon this principle was soon after augmented, by increasing the number of printing-cylinders to

four, the principle of the machine, however, remaining the same.

The manner in which this was accomplished will be easily understood by the aid of the illustrative diagram, fig. 9, where 1, 2, 3, and 4, are the printing-cylinders: P P P′ P′, are the tables of the four layers-on, and O O O′ O′, lead to those of the four takers-off. The course followed by the sheets of paper, in passing to and from the cylinders, are indicated by the arrows. Inking rollers are in this case placed at R, between the printing-cylinders; the two type-forms are inked twice, while they move from right to left, and twice again while they move from left to right. The printing-cylinders are alternately let down upon the type and raised from them in pairs; while the type-table moves from left to right, the cylinders 1 and 3 are in contact with the table, the cylinders 2 and 4 being raised from it, and, on the contrary, when it moves from right to left, the cylinders 2 and 4 are in contact with it, 1 and 3 being raised from it.

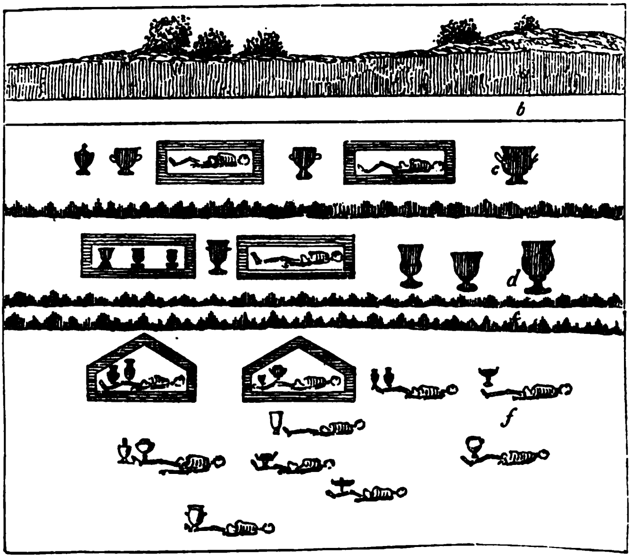
By this improvement, which was adopted in *The Times* office in 1827, the proprietors of that journal obtained the power, then unprecedented, of printing from 4000 to 5000 sheets per hour on one side of the paper. By this means they were enabled to satisfy the demands of a circulation amounting to 28000.

In reference to newspaper-printing, it must be here observed that the great object to be attained, is to increase the celerity by which printing on one side only of the sheet can be augmented. It is found convenient so to arrange the letter-press that the matter appropriated to one side of the sheet shall be ready for press at an early hour, and may be printed before the contents of the other side, in which the most recent intelligence is included, can be prepared. Hence the advantage of using machines adapted to print one side only with the most extreme celerity for newspapers.

25. **"Times" Printing-machine.**—This machine continued to serve the purposes of *The Times* newspaper until a later epoch, when again the exigencies of the press exceeded even its immense powers, and another appeal was made to the inventive genius of Mr. Applegath. It was, in short, necessary to provide a machine by which at least 10000 sheets an hour could be worked off from a single form!

In considering the means of solving this problem, it is necessary to observe, that whatever expedient may be used, the sheets of paper to be printed must be delivered one by one to the machine by an attendant. After they once enter the machine [illegible] carried through it and printed by self-acting machinery. [illegible] case of sheets so large as those of the newspapers, it is

Fig. 8.



The vases and skeletons were found at different depths and differently disposed. In some cases the vases alone were found, as at *d*; in others, the skeletons without, in others, included in sarcophagi; but in all cases the skeletons were accompanied by vases.

9. The Abbé Mazzola maintains, that notwithstanding the presence of pumice stone in the second stratum, it cannot be regarded as the direct result of volcanic action. He concludes that the superficial stratum of fertile earth is of comparatively recent formation, and that at a remote epoch the second stratum of *terra maschia* must have been superficial. Now, as the deposition of the bodies and vases under the *terra maschia* must have preceded the commencement of the formation of the present superficial stratum of vegetable soil, and as the formation of this stratum must have occupied a long succession of ages, he argues that the vases found below the *terra maschia* must have a date long anterior to that of Homer. He adds, in support of this inference, that these vases represent scenes which have never been alluded to, or described by Homer or succeeding poets, such as the combat of Neptune and Ephialtes; that these skeletons found at Nola are always

found that they cannot be delivered with the necessary precision by manipulation at a more rapid rate than two in five seconds, or twenty-five per minute, being at the rate of 1500 sheets per hour. Now, in this manner, to print at the rate of 10000 per hour, would require seven cylinders, to place which so as to be acted upon by a type-form moving alternately in a horizontal frame, in the manner already described, would present insurmountable difficulties.

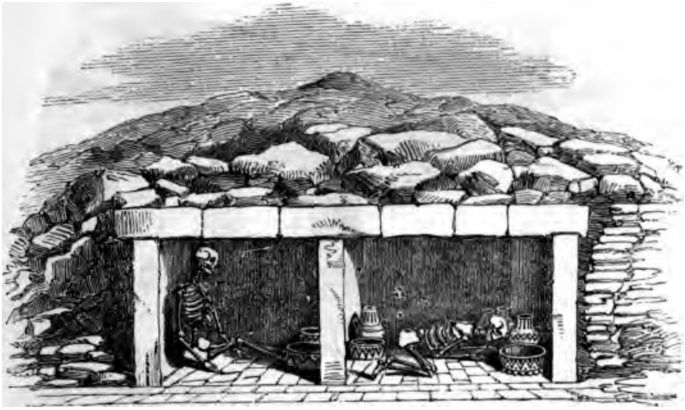
In the face of these difficulties, Mr. Applegath, to whom the world is indebted for the invention of *The Times* printing-machine, decided on abandoning the reciprocating motion of the type-form, arranging the apparatus so as to render the motion continuous. This necessarily involved circular motion, and accordingly he resolved upon attaching the columns of type to the sides of a large drum or cylinder, placed with its axis vertical, instead of the horizontal frame which had been hitherto used. A large central drum is erected, capable of being turned round its axis. Upon the sides of this drum are placed vertically the columns of type. These columns, strictly speaking, form the sides of a polygon, the centre of which coincides with the axis of the drum, but the breadth of the columns is so small compared with the diameter of the drum, that their surfaces depart very little from the regular cylindrical form. On another part of this drum is fixed the inking-table. The circumference of this drum in *The Times* printing-machine measures 200 inches, and it is consequently 64 inches in diameter.

The general form and arrangement of the machine are represented in fig. 10, where D is the great central drum which carries the type and inking tables.

This drum in *The Times* machine is surrounded by eight cylinders, R, R, &c., also placed with their axes vertical, upon which the paper is carried by tapes in the usual manner. Each of these cylinders is connected with the drum by toothed-wheels, in such a manner that their surfaces respectively must necessarily move at exactly the same velocity as the surface of the drum. And if we imagine the drum, thus in contact with these eight cylinders, to be put in motion, and to make a complete revolution, the type-form will be pressed successively against each of the eight cylinders, and if the type were previously inked, and each of the eight cylinders supplied with paper, eight sheets of paper would be printed in one revolution of the drum.

It remains, therefore, to explain, first, how the type is eight times inked in each revolution; and, secondly, how each of the eight cylinders is supplied with paper to receive their impression.

Fig. 10.



Christ, and to later dates. Specimens of these were already rare and much prized in the time of Julius Cæsar.

Among the most admired and interesting of these may be mentioned the celebrated cup of Arcesilaus. This vase is represented in plan in fig. 11, (p. 113), and in elevation in fig. 12. It is preserved in the Bibliothèque Royale, now (December, 1853) Impériale. Its height is 10 inches, and its diameter 11 inches.

This cup which was found at Vulci (Camino), in Etruria, represents Arcesilaus, King of Cyrene, seated on the deck of a vessel, the crew of which are engaged, under his superintendence, in weighing baskets of asafœtida, and depositing them in the hold.

This vase is considered to be the work of Cyrenian potters contemporary with Pindar.

13. The names of about forty of the most celebrated potters of Greece have been recorded in the works of philosophers, historians, and poets. Among these the following may be mentioned:—

Dibutades, of **Sicyon**, whose works were brought to Corinth, where they were preserved. The epoch at which this potter flourished is unknown.

Corœbus, of **Athens**, flourished in the time of Cecrops, fifteen centuries before Christ. He was reputed to have been the inventor of pottery. It will, however, be shown hereafter that this art was practised in the East at least a thousand years earlier.

Talos, the son of **Perdix**, sister to **Dædalus**. This personage them. As the inking-table attached to the revolving drum passes each of these ductor-rollers, it receives from them a coating of ink. It next encounters the inking rollers, to which it delivers over this coating. The types next, by the continued revolution of the drum, encounter these inking rollers, and receive from them a coating of ink, after which they meet the paper-cylinders, upon which they are impressed, and the printing is completed.

Thus in a single revolution of the great central drum the inking-table receives a supply eight times successively from the ductor-rollers, and delivers over that supply eight times successively to the inking rollers, which, in their turn, deliver it eight times successively to the faces of the type, from which it is conveyed finally to the eight sheets of paper held upon the eight cylinders by the tapes.

Let us now explain how the eight cylinders are supplied with paper. Over each of them is erected a sloping desk, *h*, *h*, &c., upon which a stock of unprinted paper is deposited. Beside this desk stands the layer-on, who pushes forward the paper, sheet by sheet, towards the tapes.

These tapes, seizing upon it, first draw it down in a vertical direction between tapes in the eight vertical frames, until its edges correspond with the position of the form of type on the printing-cylinder. Arrived at this position, its downward motion is stopped by a self-acting apparatus provided in the machine, and it is then impelled by vertical rollers towards the printing cylinder, these rollers having upon them marginal tapes which carry the paper round the cylinder, from which it receives the impression of the types. After this the central and lower marginal tapes dismiss the sheet of paper, which the upper ones only become charged with, and carry it to its proper place, where the tapes are stopped with the paper suspended between them, until the taker-off draws the sheets down, ranging them upon his table. These movements are continually repeated; the moment that one sheet passes from the hands of the layer-on, he supplies another, and in this manner he delivers to the machine at the average rate of two sheets every five seconds; and the same delivery taking place at each of the eight cylinders, there are sixteen sheets delivered and printed every five seconds.

It is found that by this machine in ordinary work between 10000 and 11000 per hour can be printed; but with very expert men to deliver the sheets, a still greater speed can be attained. Indeed the velocity is limited, not by any conditions affecting the machine, but by the power of the men to deliver the sheets *to it.*

In case of any misdelivery a sheet is spoilt, and, consequently, the effective performance of the machine is impaired. If, however, a still greater speed of printing were required, the same description of machine, without changing its principle, would be sufficient for the exigency; it would be necessary that the types should be surrounded with a greater number of printing cylinders.

It may be right to observe, that the cylinders and rollers are not uniformly distributed round the great central drum; they are so arranged as to leave on one side of that drum an open space equal to the width of the type form. This is necessary in order to give access to the type form so as to adjust it.

One of the practical difficulties which Mr. Applegath had to encounter in the solution of the problem, which he has so successfully effected, arose from the shock produced to the machinery by reversing the motion of the horizontal frame, which, in the old machine, carried the type-form and inking-table, a moving mass which weighed twenty-five hundred weight. This frame had a motion of 88 inches in each direction, and it was found that such a weight could not be driven through such a space with safety, at a greater rate than about forty-five strokes per minute, which limited its *maximum* producing power to 5000 sheets per hour.

Another difficulty in the construction of this vast piece of machinery was so to regulate the self-acting mechanism that the impression of the type-form should always be made in the centre of the page, and so that the space upon the paper occupied by the printed matter on one side may coincide exactly with that occupied by the printed matter on the other side.

The type-form fixed on the central drum moves at the rate of about 80 inches per second, and the paper is moved in contact with it of course at exactly the same rate. Now, if by any error in the delivery or motion of a sheet of paper, it arrive at the printing-cylinder 1-80th part of a second too soon or too late, the relative position of the columns will vary by 1-80th part of 80 inches—that is to say, by one inch. In that case the edge of the printed matter on one side would be an inch nearer to the edge of the paper than on the other side.

This is an incident which rarely happens, but when it does, a sheet, of course, is spoilt. In fact, the waste from that cause is considerably less in the present vertical machine than in the former less powerful horizontal one.

The vertical position of the inking-rollers, in which the type is only touched on its extreme surface, is more conducive to the goodness of the work than the horizontal machine, where inking-rollers act by gravity; also any dust shaken out of the paper, which formerly was deposited upon the inking-rollers, now falls upon the floor.

With this machine 50000 impressions have been taken without stopping to brush the form or table.

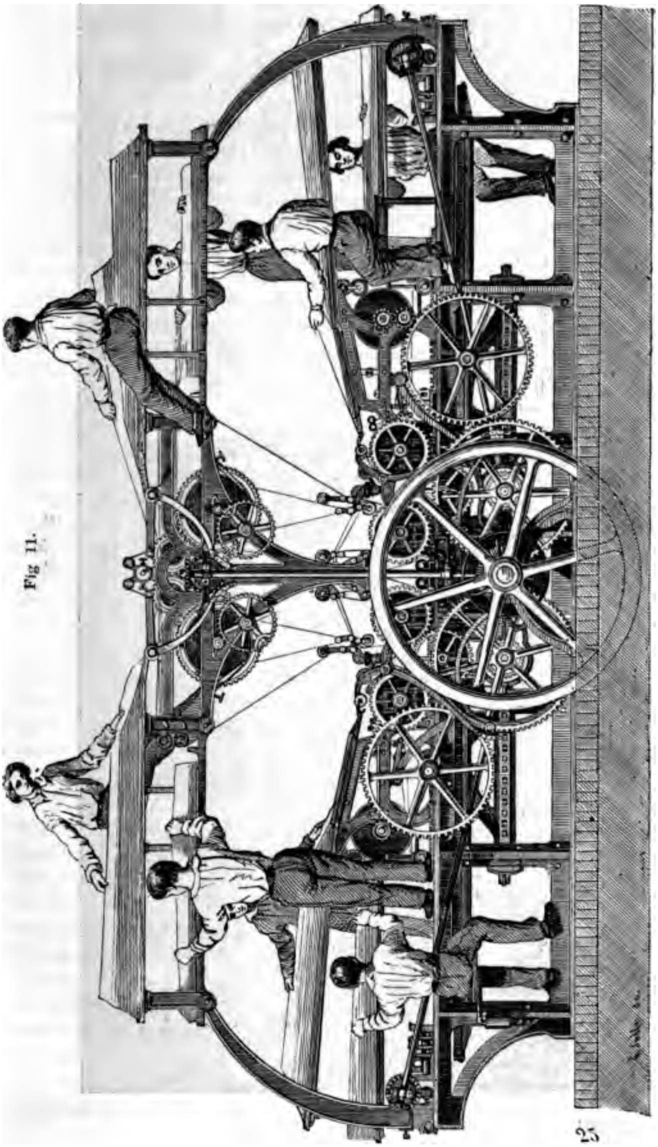
26. **Marinoni's Newspaper Printing-press.**—Messrs. Marinoni and Co., of Paris, have, within the last few years, constructed improved printing presses for newspapers of large circulation, several of which have been erected and brought into operation in the printing-office of the Paris journal *La Presse*. This printing-machine, which is capable of working off 6000 copies per hour, printed on both sides of the paper, is represented in fig. 11. It will be perceived that eight men are employed in the process, four layers-on and four takers-off. The machine is double, the parts at each side of a vertical line drawn through the axis of the fly-wheel being perfectly similar. The manner in which the sheets pass to and from the printing-rollers will be more readily understood by fig. 12, where A is the upper and A′ the lower delivering-board, and B the upper and B′ the lower receiving-board on the right, the two delivering and receiving-boards on the left being similarly placed. The motion of the sheets, as they are conducted to and from the rollers by the tapes, is indicated by arrows, and the course followed by each sheet from the moment it leaves the delivering-board until it arrives at the receiving-board, is indicated by the numbers 1, 2, 3, 4, &c. Thus, the sheet delivered from the board A is taken by the tapes which pass round the roller M, and carried from 1 to 2. Arriving at the lower roller, it passes, as shown by the arrow, between the rollers, 3, and is carried from 4 under the printing-roller I, where it is printed on one side, after which it is carried up between the tapes to 5, from whence it is discharged between the tapes of 6, and carried up over the roller R at 7, from which it is carried down between the tapes 8, and thrown, as shown by the arrow, to the tapes 9, by which it is again carried under the roller and printed on the other side; after which it is carried up successively between the tapes 10 and 11 to 12, and finally discharged from 13 at 14 upon the receiving-board B.

The sheet delivered from the lower receiving-board A′, follows a course precisely similar, entering at 1′ and passing round the printing-roller at 2′ 3′, from which it passes between the tapes 4′ round the roller R′ at 5′ 6′, and thence from the tapes 7′ 8′ round the printing-roller I′ at 9′, by which it is printed on the other side; after which it is carried by 10′, 11′, 12′ to the lower receiving-board B′ at 13′.

The inking-rollers are shown at E P D and D′, and are arranged

MARINONI'S PRINTING MACHINE.

Fig 11.



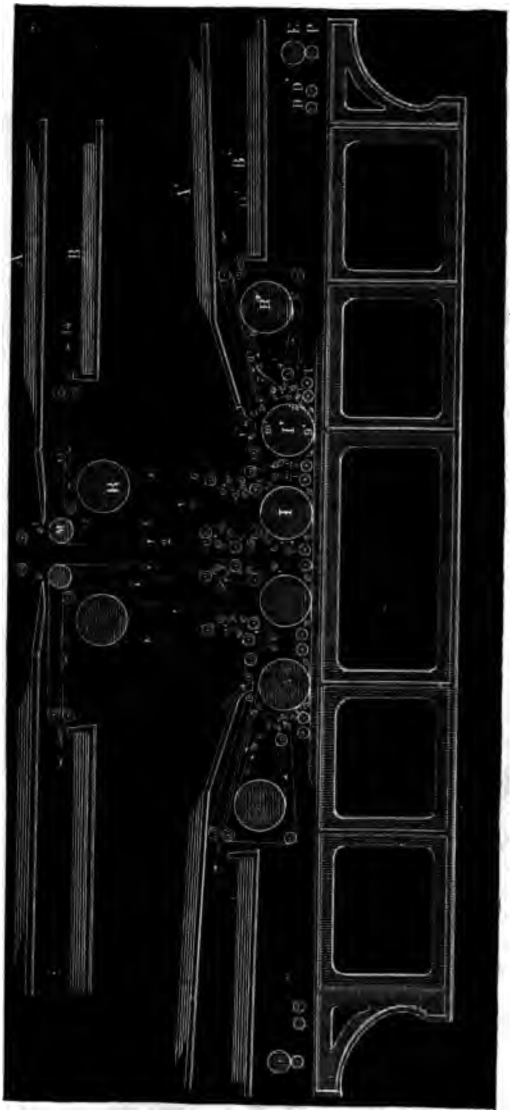


Fig. 12.

in the usual manner, at T, T', T'', T''', and T'''', to spread the ink on the types.

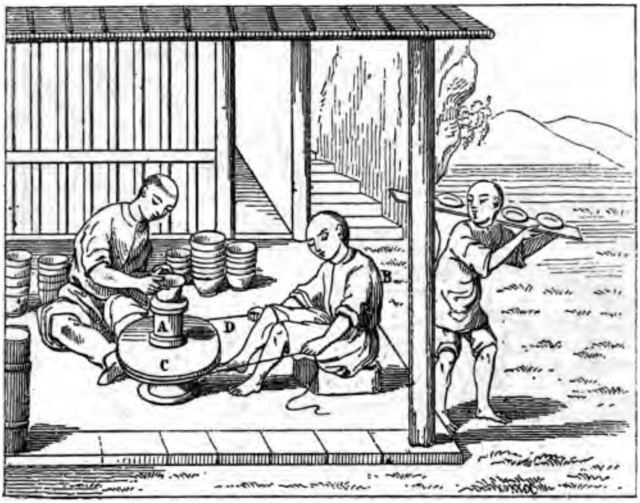
It will be perceived that the power of this press is equal to that of *The Times*, the difference being that *The Times* prints 12000 sheets on one side only, while this prints 6000 on both sides. *The Times* machine requires eight layers-on and eight takers-off, being double the number required by Marinoni's press. It must, however, be observed that, in the practical management of newspaper printing, as conducted in *The Times* office, the power of Marinoni's press, though in a certain sense equal to that of *The Times*, would be altogether insufficient; for it is indispensably necessary for that journal to print 60000 copies on one side of the paper during the last five hours of the morning. The matter allotted to the other side of the paper is so selected that it can be composed and printed in the earlier part of the night, or even of the previous day; the pressure falling exclusively on the matter which occupies the other side of the paper, consisting chiefly of the latest intelligence and Parliamentary reports.

It may be asked, therefore, how the journal of *La Presse*, of which the circulation, though inferior to that of *The Times*, is still very large, can be printed with the necessary celerity? The answer is, that *La Presse* does not contain as much as the tenth part of the letter-press of a copy of *The Times*, and that therefore, it is found practicable to compose the matter in type twice or oftener, so as to produce two or more distinct *forms*, as they are called, which are put to work at as many different presses. The expense of composition is further economised at the printing office of *La Presse* by stereotyping the matter, which is composed at a sufficiently early hour to admit of that process, the stereotype plates being melted down the next day. By this expedient double or triple composition is only necessary for the intelligence which comes too late to allow of being stereotyped.

27. **Marinoni's Book-printing Machine.**—A convenient form of printing-engine for books, constructed by the same engineers, is shown in fig. 13, by which, however, the sheets are printed on one side only. The layer-on delivers the sheets upon the board M (fig. 14), from which they pass round the printing roller I, and are discharged as indicated by the arrow upon the receiving-board R. The rollers for delivering and spreading the ink on the types are arranged in the usual way.

28. **Newspapers.**—Of all the applications of printing to the uses of life, that which has conduced most to the advancement and improvement of the art has been the printing of newspapers. These organs of public opinion and intelligence combine the conditions which require from the printing press the greatest con-

Fig. 20.



yielding to its motion at the other end. After each impulse the strap is loosened and restored to its first position on the edge in order to repeat the impulse. The strap is prevented from slipping over the surface of the edge of the wheel by pins or points projecting from its surface.

The potter places the paste to be formed into the desired article on the head of the wheel, and shapes it with his hands and fingers.

Another man is represented carrying away the finished articles to the oven.

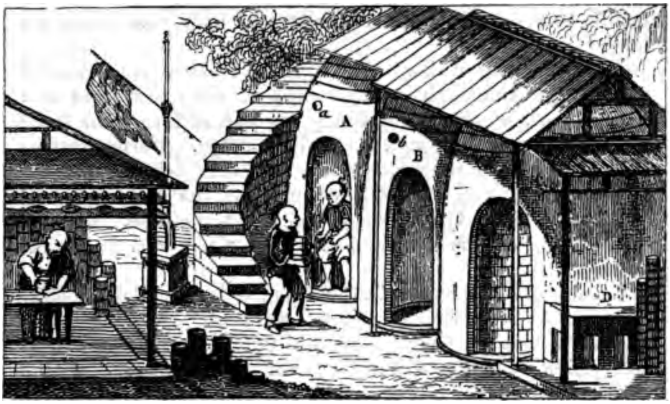
5. The ovens and the process of baking are represented in fig. 21. A man in a shed on the left is employed in placing the articles to be baked in cylindrical cases of baked earth, which correspond to those which our potters call SAGGERS.

An empty oven is represented at A, where a man receives the saggers filled with the articles to be baked, and arranges them in the oven. When the oven is thus filled it is closed by brickwork. A second oven thus filled, and bricked up, is represented at C.

The fire doors or feeding mouths of the furnaces, by which the ovens are heated, appear at D, and the openings for the escape of smoke and the products of the combustion are represented at *a*, *b*, and *c*.

ANCIENT CHINESE POTTERIES

Fig. 21.



The Chinese ovens used at the present time do not differ much in form or arrangement from those designed and described by Entrecolles in the beginning of the last century. M. Chavagnon, who witnessed their performance at a recent period, says that the construction of the flues is so well managed, that the distribution of the heat is sensibly uniform, the ovens such as A, which are most remote from the furnace, being as effectually heated, and the articles in them as well baked, as those, such as C, which are nearest to it.

6. The first attempts made in Europe to fabricate a hard earthenware covered with a glaze, are ascribed to the Moors of the Spanish Peninsula. After this, a manufacture upon a large scale, was established in the Balearic Isles; and the wares originally produced there, and subsequently reproduced in Italy, acquired the name *Majolica*, being a corruption of Majorica or Majorca, the principal island of the Balearic group.

7. The first of the improvers of this art after its importation into the Italian peninsula, was Lucca della Robbia, a Florentine sculptor, whose name has thus become inseparably associated with the history of this ornamental industry. This celebrated artist, born in 1388, died prematurely in his forty-second year. He left, nevertheless, an immense number of works, which have come down to the present times, and are highly prized.

He was succeeded by his brothers and their descendants, all of whom continued, for nearly a century and a half, to practise the art on a large scale, so that it must be always difficult, if indeed it be possible, to ascertain what are the genuine works of the great artist, and to distinguish them from those of his family, some of whom worked under and with him during his lifetime.

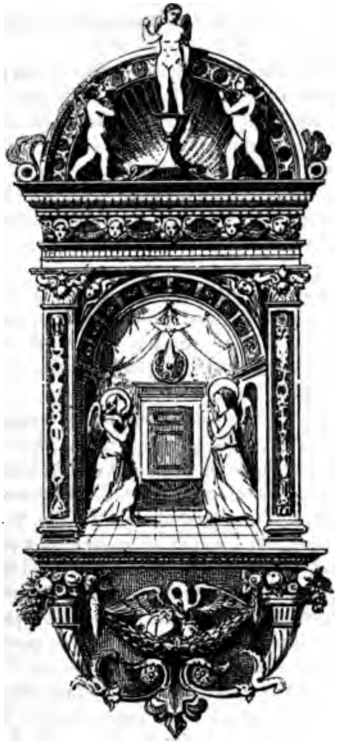
The productions of this family of artistic potters are formed of a paste, consisting of about 50 per cent. of silica, combined with 15½ per cent. of alumina and 22½ per cent. of lime, with small proportions of carbonic acid, magnesia, and iron. The decorations were figures in relief, variously coloured with yellow, produced by lead and antimony, a dark opaque blue, the green produced by copper, and a bad violet produced by manganese. The art of producing colours by means of gold was not then known in Europe.

8. In fig. 22 is represented an altar-screen by Lucca della Robbia. This consists of four pieces and two pilasters. The ground is a fine azure blue; the figures are white; the fruits, cup, &c., in gold-yellow, and the garlands green. The thickness of the earthen ware or *faiençe*, of which it is composed, is little more than an inch and an half. This piece is preserved in the Cabinet SAUVAGEOT.

9. The paste used at this epoch not having the whiteness of the finer porcelain, the articles fabricated were covered with an opaque glaze of some particular colours, by which the coarse and ill-coloured ground of the porcelain was concealed. The process by which these opaque glazes were produced was nearly the same as that by which the transparent and colourless glazes of the present day are produced. The baked article, which before it is glazed is called biscuit, is submerged in a vessel containing the vitrifiable matter, mixed with such a proportion of water as to give it a creamy consistency. After immersion, a coating of this liquid adheres to the surface. The water which holds the vitrifiable substance in suspension is partly imbibed by the material of the vessel. The vessel, thus coated, is placed in an oven, and again exposed to the action of heat of sufficient intensity to vitrify the coating with which it is invested, so that, when withdrawn from the oven, the coating is converted into a coloured and opaque glass, and the vessel is glazed. Sometimes the article, before being baked, was covered with a coat of earthy matter, not vitrifiable but opaque, by which the coarse surface of the paste was concealed, and this coat being hardened in the oven, a transparent glaze was put over it.

10. The majolica ware of Italy was in its most flourishing state from 1540 to 1560. It was during this interval that the finest table-services were produced. The chief places of its fabrication were Castel Durante and Florence; but its celebrity and the

Fig. 22.



ALTAR SCREEN BY LUCCA DELLA ROBBIA.—1400 A.D.

general taste for it increasing, all the principal Italian cities produced it, and all the most renowned artists, including Raphael himself, supplied designs for it, which potters scarcely less renowned, executed.

It has been often stated that Raphael himself worked at this art. Such, however, was not the fact. The Duke of Tuscany, Guidobaldo II., who extended to this art the most magnificent patronage and encouragement, procured designs from Raphael and his pupils, which he gave to the potters whom he had established at Pesaro to execute; and it happened that among the most skilful of the decorators of these potteries there were two who bore the name of Raphael. Hence the productions were said to be those of Raphael; and, at a later period, those who were unacquainted with these circumstances concluded that they were the immediate work of the celebrated painter.

11. It was at this time that the celebrity of such productions, and the universal admiration which they excited, produced the custom, continued to the present time, of offering them as royal presents by sovereign to sovereign. The Duke Guidobaldo caused to be executed at Pesaro magnificent services, which he presented to sovereigns and other eminent personages. The splendid service is especially mentioned which he presented to the Emperor Charles V., made by Taddeo Zucarro and Battista Franca, under the direction of the brothers Flaminio and Orazzio Fontana.

Nothing was omitted which could enhance the interest and increase the excellence of those productions of artistic industry. To genius, talent, skill, and care, were united the researches of erudition, and the counsels of taste, to impart to them the greatest attainable perfection.

12. This high excellence was sustained so long as the art was protected and fostered by royal patronage. The time was not yet arrived when the patronage of the public was more advantageous than that of the sovereign; and after the decease of Guidobaldo and Orazzio Fontana, the art being left to the unaided influence of the public demand, it became necessary to meet that demand by low-priced and, therefore, inferior articles. The taste accordingly declined with the excellence which excited it, and the Italian majolica gradually but speedily lost its reputation.

About 1772, Cardinal Stoppani attempted to revive it at Urbino, and some temporary effect was produced about 1775, but it was only temporary. It is probable that the importation of Chinese porcelain into Europe, which was simultaneous with the decadence of majolica, may have had some influence in producing that result.

13. The epoch of della Robbia in Italy was followed by that of Bernard Palissy in France. This eminent potter was born at La Chapelle-Biron, a small village of the Perigord, about 1510, and died in 1589.

Although he was the author of many published works, and one upon the art which he practised with so much success, he has left no available information respecting his processes. His desire seems to have been exclusively to leave to the world a record of the unparalleled difficulties he encountered, the sacrifices he made, the sufferings he endured, and the obstinate perseverance, amounting, it must be admitted, to a sort of heroism, which he displayed in the attainment of his objects. In his experiments, which were continued for a long period of time, and pursued with an admirable patience, he expended all that he was worth, even to the sale of his furniture and wardrobe.

Palissy had the weakness and ignorance so common with practical men, of inveighing against theory, yet in the only work which he has left on the subject of his art, he has not only been sparing, obscure, and mysterious in his practical details, but has mixed them up with theories of his own which only prove how much painful toil, how many abortive experiments, and how great an expenditure he would have been spared, had he condescended to consult those who were qualified to inform him of the true principles of physical and chemical sciences applicable to his researches.

14. The character of this great improver of his art was strongly marked, not only by patience, perseverance and sagacity, in the pursuit of his purposes, but by eminently high moral firmness, and unshaken rectitude. No example can be found of one to whom the well-known lines of the Roman poet are more truly applicable:

> "Justum ac tenacem propositi virum,
> Non civium ardor prava jubentium,
> Non vultus instantis tyranni
> Mente quatit solida."—Horace.

> "The man, in conscious virtue bold,
> Who dares his secret purpose hold,
> Unshaken hears the crowd's tumultuous cries,
> And th' impetuous tyrant's angry brow defies."
> Francis.

15. Palissy was a conscientious Protestant, and did not hesitate publicly to avow and express his opinions even in his discourses on subjects of his art. By this boldness and indiscretion, he was in his ninetieth year dragged before the ecclesiastical authorities, and refusing peremptorily to renounce his opinions, or to retract his expressions, he was thrown into the Bastille. He was visited there by the King, Henry III., who wished to liberate him, when the following memorable colloquy took place between the monarch and the manufacturer:

"My good man," said the king, "if you cannot conform yourself on the matter of religion, I shall be compelled to leave you in the hands of my enemies."—"Sire," replied the old man, "I was already willing to surrender my life, and could any regret have accompanied the action, it must assuredly have vanished upon hearing the great King of France say 'I am compelled.' This, sire, is a condition to which those who force *you* to act contrary to your own good disposition can never reduce *me;*

because I am prepared for death, and because your whole people have not the power to compel a simple potter to bend his knee before images which he has made."

Palissy, to the eternal disgrace of the monarch and the priests, was detained in the Bastille, where he died at little short of a hundred.

16. The works of Palissy are characterised by a peculiar style and qualities. While the forms are in general correct and pure, there is no painting properly so called. The figures are given in coloured relief, whether they be mere ornaments, representations of natural objects, or historical, mythological, or allegorical subjects. The enamel is hard and brilliant, but often disfigured by a multitude of small inequalities; a defect which is also observable in the productions of the German potters of that day. The colours are generally brilliant, but little varied. The white is yellowish, and very inferior to that of della Robbia. The other tints are confined to a pure yellow, an ochre yellow, a fine indigo blue, a greyish blue, an emerald green, a yellowish green, the violet produced by manganese, and a brownish violet. They included no fine white, nor any tint of red.

The bottoms of the articles are generally marbled with tints of blue, yellow, and brownish violet.

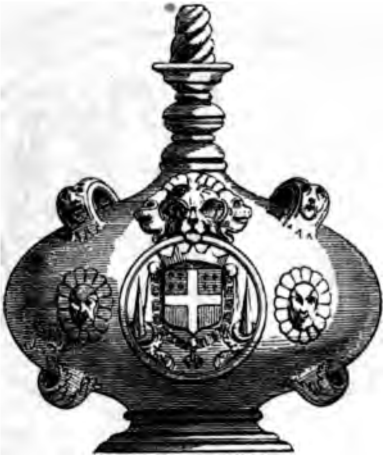
In fig. 23 is represented a porcelain flask (Bouteille de Chasse), attributed to this potter, preserved in the *Cabinet Sauvageot.* It is oval in form, the largest diameter being 10¼ inches, and bears the Montmorenci arms. Palissy was employed by the Duc de Montmorenci to decorate the Château d' Ecouen.

The natural objects represented on the pieces of Palissy, are remarkable for truth of form and colour, having been, with the exception of certain leaves, moulded from nature. It would appear from the selection of this class of decoration that Palissy was more or less a naturalist. The shells with which he has ornamented many of his pieces are all tertiary fossil shells from the Paris basin, and probably also that of Grignon and its environs. The fishes are those of the Seine, and the reptiles, a prevailing subject, those of the banks of the same river.

Most of the pieces, and especially the dishes and plateaux, are surcharged with objects in coloured relief, and evidently were never designed for the table, but were used to furnish the great buffets and sideboards called Dressers, which were placed in the dining halls of that day.

The productions of this potter must have been extremely numerous, for they are still found in great quantities in the cabinets and collections, public and private, and with the vendors of antiquities and curiosities of all countries. The varieties of

Fig. 23.



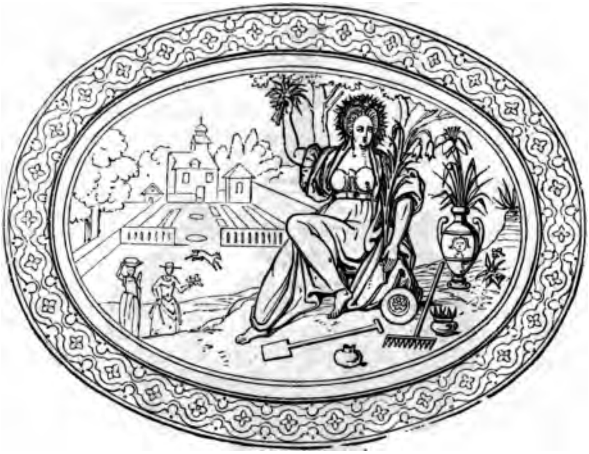
form and design, however, bore no proportion to the number of articles produced, and we accordingly find a limited number of forms and patterns, indefinitely repeated in the extant collections.

17. An oval plateau highly decorated in relief by this potter is represented in fig. 24. This piece is well known to amateurs under the name of the dish of the fair garden-girl, *plat de la Belle Jardinière*. The decorations, coloured yellow and green, are in low relief. The bottom is scaled green and reddish yellow. This piece is in the collection Sauvageot.

18. Between the middle of the seventeenth century and its close commenced the manufacture of the fine earthenware, which, without attaining the excellence of porcelain, constituted a great improvement on the previous products of this industry. This was owing partly to the discovery of a white plastic clay as a substitute for the reddish clay previously used in France, Germany, and Italy, which rendered it possible to use a colourless transparent glaze instead of the opaque coloured glaze, which had been previously used. Besides this, there were numerous improvements made in the details of the manufacture by the potters who established themselves in Staffordshire, and gave celebrity to the extensive district since known as the Potteries.

The establishment of this industry in Staffordshire originated from the circumstance of strata of good plastic clay being found

Fig. 24.



there in immediate juxta-position with the coal necessary for its conversion into the fabricated article.

The chief town of the district, Burslem, is supposed to derive its name from two Saxon words, BURN or BYRN, a *stream* or a *farm*, and LŒM, *clay*. If this be the origin of the name, it would follow that the fabrication of earthenware in that district must have prevailed since a very remote epoch.

19. About 1680, Messrs. Palmer and Bagnall, potters at Burslem, discovered accidentally the property of marine salt, by which it supplied a glaze. In some culinary process, salt being thrown into the fire its vapour came in contact with the biscuit of an unglazed article, and was observed to have the effect of giving it a glaze. The expedient was tried in the manufacture, and succeeded. The salt, when vaporised, coming in contact with the unglazed ware, was decomposed by the silica which formed so large an ingredient of the paste, and the soda deposited combining with the silica produced the glaze.

It was about this time that the brothers Elers of Nuremberg immigrated to England, and erected a small factory in Staffordshire. There were then no more than twenty-two ovens at Burslem.

20. The Messrs. Elers had not long been there before they discovered in the neighbourhood a bed of clay of very superior quality, and, erecting upon the spot itself a factory, resorted to

extraordinary and curious measures to keep in profound secrecy their materials and their processes. With this view they not only excluded most rigorously from their works all visitors whatever, but selected for their operatives the most stupid and ignorant persons they could find, and so divided the labour that no one individual possessed more knowledge than that of the very process at which he was employed. These precautions were, however, of little avail. The stimulus of profit and the spirit of enterprise are not to be repressed by such shallow expedients. A workman named Twyford imposed upon them by affecting indifference to the art, and managed to get admitted to their employment. He soon ascertained some of their secrets, but it remained for another more astute and persevering person to discover all the details of their processes. An individual named Astbury, appreciating the importance of the manufacture, and foreseeing the profits likely to arise from it, decided on adopting a course and persevering in it, which, as he imagined, and as proved by the event, would lead to a complete discovery. He affected the manners of an idiot, deceived them, and got into their employment, and was adroit enough to sustain the deception for several years, until he became complete master of their secrets. After this, the Messrs. Elers left Staffordshire in apparent disgust, and settled in London, where, at a later period, they were probably instrumental in establishing the well-known porcelain works at Chelsea.

21. One of the ingredients of fine pottery is silica, or the earth of flints. The circumstance which led to the application of this substance to the art is thus related:—Mr. Astbury, the son and successor of him who gained the knowledge of the Elers's secret by feigning idiocy, being on his road to London, and making the journey on horseback, was stopped at Dunstable in consequence of his horse being attacked with a malady of the eyes. The innkeeper at whose house he put up advised him to apply a poultice of calcined flints. Astbury observed that the flints, which before calcination were black, and semi-transparent, were by this process of calcination converted into a white opaque substance. It occurred to him that he might by like means bleach the clay of which the pottery was made, and which was reddish in its colour, by mixing with it more or less of the matter thus whitened in the fire. He accordingly realised this idea with complete success, and silica or the earth of flints became thenceforward a necessary ingredient of the paste.

22. Among the improvers and inventors of this epoch the most memorable was Josiah Wedgwood, whose name has since become so inseparably connected with this branch of the national industry.

This celebrated potter, born at Burslem in 1730, was the son of Thomas Wedgwood, who followed the same business. The education of Josiah must necessarily have been limited to reading and writing, for at the early age of eleven years he worked at the wheel in his father's pottery.

After being united in partnership for short intervals with Messrs. Harrison and Whieldon, he commenced working on his own account in a little thatched building, in 1760. He soon extended his works, erecting another small manufactory called the "Bell Works," from the fact, then unusual, that the workmen were assembled and dismissed by a bell. It was here that he commenced the fabrication of the cream-coloured ware, with a plombiferous glaze, which afterwards became so celebrated, and which being approved and patronised by Queen Charlotte, consort of George III., was called *Queen's ware*, and procured for Wedgwood the appointment of potter to the Queen.

Wedgwood was esteemed as much for his public spirit and private virtues as for his industrial enterprise and skill. It was to him was chiefly due the construction of the canal connecting the Trent with the Mersey, commenced in 1760, and completed in 1777.

His fortune being increased by inheritance as well as by his commercial success, he purchased the estate called Ridge House, where he established, in 1770, his manufactory of black ware.

It was here also that he erected the noble mansion which became his family residence, and the surrounding village called ETRURIA, where he established his principal works, having removed from Burslem in 1771, and where he accumulated that princely fortune, which he devoted to so many noble and charitable uses. The name conferred on this establishment, and the industrial village created around it, was taken from that of one of the ancient Italian states, which had attained a high celebrity for the tasteful forms of its potteries.

He died at Etruria, in 1795, at the age of 64.

The effects of the genius and perseverance of this prince of manufacturers were not limited to the improvement of the mere processes of fabrication. His efforts were directed with not less success and effect to the improvement of forms and decoration. He resolutely rejected the uncouth and distorted shapes which had till then prevailed, and replaced them by forms at once pure, simple and elegant. He availed himself of the collection of ancient vases, which Hamilton had brought from Italy, and took his models from them. He substituted for the vulgar style of ornament which had been till then exclusively adopted, decorations characterised by a severe taste, and, like the earlier potters of Tuscany, he called to his aid the greatest living artists, procuring designs from the celebrated Flaxman, according to which he fabricated his improved wares. This system has been continued by his son and successor.

Wedgwood was as remarkable for enlightened liberality in his private character as for well-directed enterprise as a manufacturer. An example of his munificence was lately mentioned in one of the leading journals, which we cannot pass without mention here. The family attracted around them men of genius in literature and art, among whom were Sir James Mackintosh, his brother-in-law, Mr. Stuart, then editor of the *Morning Post*, Coleridge, Southey, and others. In the beginning of 1798, Coleridge received an invitation to accept the functions of minister to the Unitarian congregation at Shrewsbury. Thomas Wedgwood hearing of this wrote to him to dissuade him from taking such a step, considering it to be adverse to the prosecution of literary works, in which he was likely to found a great reputation, and to confer a great benefit on society; and that no immediate pecuniary exigency should force him to accept the proposition he enclosed a cheque for an hundred pounds. Coleridge, however, considering that the Shrewsbury appointment opened to him for the first time in his life the prospect of a certain income and permanent establishment, decided to accept it, and returned the cheque. He accordingly went to Shrewsbury, preached his probation sermon with general satisfaction to his flock, the afterwards celebrated William Hazlitt being one of his auditors. The Wedgwoods, however, sensible that the poet was misplaced, and would be lost to the world, again wrote to him, expressing that opinion, and proposed that he should at once relinquish his clerical charge, to which he was unsuited, and with princely munificence offered to place him at ease for the future by settling on him a life annuity of an hundred and fifty pounds. The offer was promptly and gratefully accepted.*

Before the commencement of Wedgwood's labours the English potteries produced wares flimsy in their materials, grotesque in their forms, and utterly destitute of all correct taste in their ornamentation, being miserable copies of the Chinese procelain. Owing to the influence of the enterprise and genius of this eminent man, the style and character of the ceramic manufacture of the country was thoroughly reformed, so that not only have the productions of Staffordshire, Derbyshire, Worcestershire, London, and other places where this industry has been established, superseded foreign goods in the home market, but they have spread over the whole civilised world. M. Faujas de St. Fond, a foreign writer on this subject, says:—

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* Edinburgh Review, April 1848, p. 379.

"The excellent workmanship of English porcelain, its solidity, the advantage which it possesses of sustaining the action of fire, its fine glaze, impenetrable to acids, the beauty and convenience of its form, and the cheapness of its price, have given rise to a commerce so active and universal, that in travelling from Paris to St. Petersburgh, from Amsterdam to the furthest part of Sweden, or from Dunkirk to the extremity of the south of France, one is served at every inn upon English ware. Spain, Portugal, and Italy are supplied with it, and vessels are loaded with it for both the Indies and the continent of America."

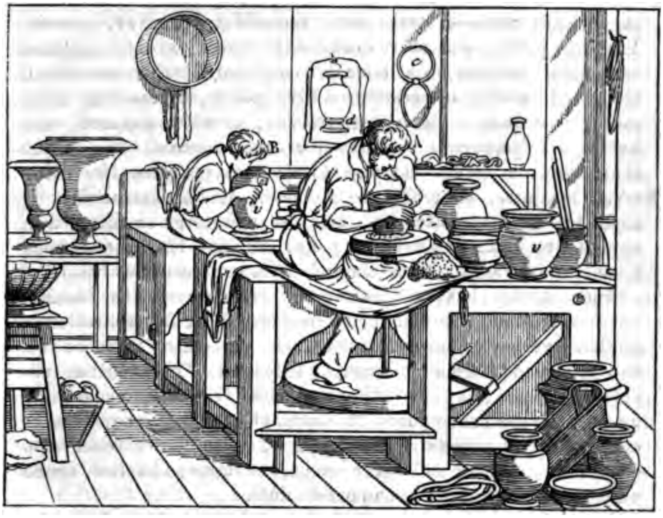

Fig. 28.—TURNER OR THROWER'S SHOP IN PORCELAIN WORKS.

THE POTTER'S ART.

CHAPTER III.

1. Improvements effected by Wedgwood.—2. General commercial advantages attending the manufacture.—3. History of Chinese porcelain. —4. Its first importation into Europe.—5. Great plasticity of the material.—6. Perfection of its forms.—7. Pagoda of Nankin.— 8. Forms of vases.—9. Figure called "pou-sa."—10. Discovery of the material of porcelain in Europe.—11. Origin and history of Böttger.—12. His labours in Saxony.—13. Anecdotes of his imprisonment.—14. Is established at Dresden.—15. First results of his labours.—16. White earth of Schnorr.—17. Discovery of Saxon kaolin.—18. Establishment of the royal manufactory at Meissen.— 19. Curious precautions to ensure secresy. — 20. Anecdote of Brongniart.—21. Death of Böttger.—22. Analysis of the Dresden paste.—23. Style of the Dresden porcelain.—24. Grotesque figures. 25. Secrets transpire.—26. Ringler at Hochst.—27. Paul Becker.— 28. Establishment of the Royal Bavarian manufactory.—29. In other German states.—30. Invention of the Sèvres *pâte tendre*.—31. Its defects.

1. Among the principal improvements for which the art is indebted to the genius of Wedgwood, may be mentioned—besides

the queen's ware—a terra cotta resembling porphyry, granite, Egyptian pebble, and other ornamental stones; a black unglazed ware called basaltes, hard enough to emit sparks when struck with steel, and capable of receiving a high polish, of resisting acids, and of sustaining a high temperature; a white unglazed ware having like properties; a bamboo or cane-coloured ware of the same kind; a biscuit adapted to chemical purposes by reason of its hardness, its resistance to acids, its impenetrability by liquids; its incorrosiveness, and its refractory quality when exposed to high temperatures; and, in fine, for a production denominated JASPER, consisting of a white porcelainous biscuit of extreme beauty, having besides the properties of the basaltes above-mentioned, the quality of receiving from the application of metallic oxides colours which penetrate its entire thickness like those imparted to glass or enamel in fusion. This peculiar property, possessed by no other porcelain or earthenware body ancient or modern, renders it applicable to the production of cameos and all subjects which require to be shown in relief upon a ground of another and darker colour, the figures in relief formed with this biscuit being of the purest white.

2. We cannot give a more clear idea of the benefits conferred by this manufacture on our national industry than may be obtained from the following evidence, given by Wedgwood before a Parliamentary committee:—

"Though the manufacturing part alone in the Potteries, and their immediate vicinity, gives bread to 15 or 20,000 people, yet this is but a small object when compared with the many others which depend on it; namely, 1st, The immense quantity of inland carriage it creates throughout the kingdom, both for its raw materials and finished goods. 2nd, The great number of people employed in the extensive collieries for its use. 3rd, The still greater number employed in raising and preparing its raw materials in several distant parts of England, from near the Land's End, in Cornwall—one way along different parts of the coast, to Falmouth, Teignmouth, Exeter, Pool, Gravesend, and the Norfolk coast; the other way to Biddeford, Wales, and the Irish coast. 4th, The coasting vessels, which, after having been employed at the proper season in the Newfoundland fishery, carry these materials coastwise to Liverpool and Hull, to the amount of more than 20,000 tons yearly; and at times when, without this employment, they would be laid up idle in harbour. 5th, The further conveyance of these materials from those ports, by river and canal navigation, to the Potteries, situated in one of the most inland parts of this kingdom; and, 6th, The re-conveyance of the finished goods to the different parts of this island, where they are shipped for every foreign market that is open to the earthenwares of England."

Mr. Wedgwood very justly observed further, that this manufacture is attended with some circumstances of advantage which are almost peculiar to itself; viz. that the value of the finished goods consists almost wholly in the labour bestowed upon them; that every ton of raw materials produces several tons of merchandise for shipping, the freight being paid, not upon the weight, but according to the bulk; that scarcely a vessel leaves any of our ports whose lading is not in part made up of these cheap, bulky, and, for these reasons, valuable articles, to this maritime country; and that fully five parts in six of the aggregate manufactures of the Potteries are exported to foreign markets.

3. While the potters of Europe were engaged with more or less success in the fabrication of an earthenware, which, whatever may have been its merits, was formed of a paste coarse and opaque; the fine porcelain, which attracted so much and so well merited admiration, was for a long period of time obtained exclusively from the East.

Without insisting on the claims of the Chinese to the production of this beautiful article at the epochs of remote antiquity, which have been already referred to, there is sufficiently conclusive evidence that they possessed and practised the art hundreds of years before it was discovered in Europe or elsewhere. Thus it is certain that fine porcelain was made in China 163 B.C., and that its fabrication existed still in 442, A.D.

The first porcelain oven, however, of which there are distinct and detailed historic records in China was called TAOU-YAOU, and was situate at Chang-Nan in the province of KEANG-SI. Tributes of porcelain were sent from this factory to the court of Woo-tih in the year 630 A.D.*

The celebrated works of King-Te-Tching, already mentioned, were not established until 1000 A.D.

In the Ceramic Museum of Dresden are pieces of porcelain which bear dates from 1403 to 1425, from 1465 to 1488, and 1573 to 1620, which are, therefore, spread over two centuries. The stationary character of the Chinese is remarkably indicated by the fact that the earliest of these specimens does not differ in the slightest degree from the latest, either in its mode of fabrication, the nature of its material, nor even in its colours or style of decoration.

4. It was not until 1518 that the Chinese porcelain was brought to Europe by the Portuguese, and two centuries elapsed before any successful attempt was made to fabricate it. In England this fine

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* Morrison's Chinese Dictionary, part iii., p. 326, word "porcelain."

pottery was called CHINA, from the place of its production, but on the Continent it was distinguished from the coarser sorts of pottery by the name porcelain; the origin of which is not certain, but which is supposed to be derived from the Portuguese word PORCELLANA (a drinking cup).

Although the art of fabricating porcelain was thus late in reaching Europe, it extended from China to other adjacent parts of Asia, and especially to Japan, and even to Persia, at a much earlier period.

5. The paste of which the oriental porcelain is composed is generally deficient in pure whiteness, having rather a grayish hue, while the glaze which covers it is greenish. It is hard, brittle, and stands the fire only with many precautions. It is not as translucent as the fine porcelain manufactured in France and Germany.

That in its unbaked state it possesses the quality of plasticity in an extraordinary degree is rendered manifest by various circumstances. The process of the fabrication is one to which no material but the most plastic could lend itself. It is also proved by the enormous magnitude of the vases which are fabricated in a single piece, free from those defects which would be inevitable with a material not possessing that quality in the highest degree.

Without being as fusible as the paste of which the tender porcelain is formed, it is less infusible than that of the hard European porcelain. A cup of Chinese porcelain was softened and distorted in one of the Sèvres ovens.

6. The forms given to the Chinese porcelain are remarkable for their perfection, even in the case of articles presenting the greatest difficulties and delicacies. The pieces, although large, are frequently not thicker than an egg shell. Open cylindrical vases eight or nine inches in height are proportionally delicate; plates decorated with ornaments in relief, are remarkable for their lightness and evenness of surface; and as to magnitude, the vases made in a single piece are sometimes fifty-four inches high and twenty-two inches diameter. A vase of these dimensions is in the possession of M. Cambacères, remarkable for the magnificence of its ornamentation in relief, and its dragon-formed handles.

7. Among the pieces of Chinese porcelain most memorable for magnitude, is the celebrated pagoda of Nankin in the province of Kiang-Ming, the height of which is 213 feet. This structure consists of nine stages, the walls of each of which are covered with plates of coarse porcelain. Two models of this, on a small scale, may be seen in the Imperial (Royal) Library at Paris.

8. One of the most characteristic forms of the Chinese vases is

that of the two round vases or bottles connected by a contracted neck, of which figs. 25 and 26 are examples. The most usual ornaments on these vases are lizards or other reptiles with a curved and bifurcated tail, which are represented crawling from one of the vases to the other in the contracted neck, by which they are connected.

Fig. 25.

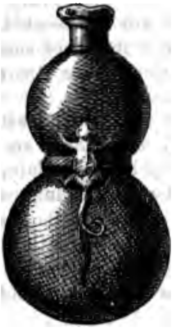
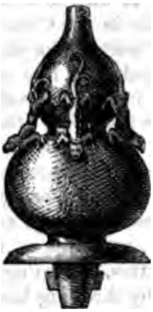
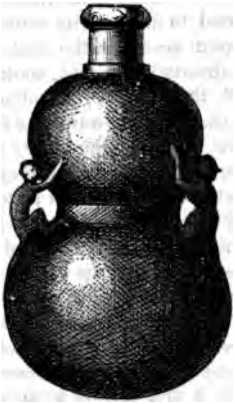


Fig. 26.



This form of vase has been seen no where on the old continent except in China and in Egypt. M. Brongniart, however, notices

Fig. 27.



a fact which has some interest for geographers and antiquaries. It is that vases of the same form and similar decoration have been found among the remains of ancient pottery in Peru and Chili in South America, which must have existed ages before the time of Columbus. One of these jars, found in Peru, is represented in fig. 27. It will be observed as a coincidence deserving of notice, that while in the Chinese vases lizards are represented creeping from one part of the vase to the other, a species of small ape is represented in a like position and action on the Peruvian vase, and that in both cases the tails are bifurcated.

9. The figures so often seen on Chinese porcelain, with a large paunch, which amateurs call POU-SA, and which are often in coloured glaze, represent the Chinese god of porcelain, whom a legend records as being a martyr to the art. Being engaged in the process of baking, he found that the action of the furnace was irregular, and such as must destroy the articles in the oven. To prevent this, according to the Chinese traditions, he sacrificed himself by throwing himself bodily into the furnace, and attained his object.

10. It was not until the beginning of the last century that the art of fabricating the true porcelain made its way to Europe. The circumstances attending its discovery are highly interesting and curious.

During the seventeenth century, the oriental porcelain which had been brought to Europe by the Portuguese, and which was distinguished from the wares fabricated there by the name of porcelain, excited the unbounded admiration of all classes. No efforts were left untried to discover its materials and the means of producing it. European agents in the East, and more particularly Father Entrecolles already mentioned, contrived, in spite of the jealous vigilance of the Chinese, to obtain specimens of the materials of which the precious ware was fabricated. But these materials were in the state in which they were prepared for the potter, and not in the raw form in which they were first taken from the quarries. Nevertheless, they were assiduously examined and analysed by the most eminent chemists and physicists of the day.

These researches, however, led to no practical result; and, as so often happens in the progress of discovery, as well in the arts as in the sciences, chance accomplished what sagacity and industry failed to attain. Even chance, however, can accomplish nothing, unless it presents its results where talent and genius are present to recognise them and turn them to account. Happily, in the present case, the talent and genius were not wanting. Saxony was destined to have the honour of the first accomplishment of this great advance in the ornamental arts.

ANECDOTES OF BÖTTGER.

11. John Frederick Böttger (or Böttcher) was born at Schlaiz, in Voigtland, on the 4th of February, 1682. He was brought up at Magdeburg, where his father had a place in the Mint. The father was given to alchemy, and pretended to the discovery of the philosopher's stone, the secret of which he was reputed to have imparted to his son. In the superstitious spirit of the age, Böttger believed himself gifted with the power of divining the future, in consequence of being a "Sabbath child," having chanced to come into the world on a Sunday.

He was apprenticed to an apothecary named Zorn, at Berlin, but the fascinations of alchemy did not long permit him to give his attention to the preparation of medicines; and he deserted his master and his business. He was soon, however, obliged to return, and was received and forgiven, on the condition of abandoning his favourite study of alchemy.

Soon after this, being informed that the fame of his researches and the rumours of his prospects of successful results, which gave him among his fellow citizens the name of the "Goldmaker," had reached the ears of Frederick I. of Prussia, and fearing, or affecting to fear, that he would be seized by royal order for the purpose of extorting his secret from him, he again fled, and took refuge in Saxony, where his arrest was procured by the Prussian authorities. The Elector of Saxony, however, having resolved not to surrender so precious a personage, had him carried away from Wittemberg, and secretly confined, but well cared for and treated.

He was supplied with all the means necessary to carry on his chemical researches, but was kept under constant surveillance, and was in reality a prisoner.

12. After some time the Elector, finding that the labours and researches of Böttger were without any practical results, and suspecting all the prospects of success so much vaunted to be mere illusions, but finding nevertheless that his protegé and prisoner was endowed with considerable natural genius, combined with much acquaintance with chemical science, such as it was at that time, resolved on endeavouring to turn Böttger to better account; and, with this view, put him in communication with EHRENFRIED WALTHER DE TSCHIRNHAUSEN, who was then occupied in experimental researches directed to the improvement of the fabrication of earthenware, and more especially to the discovery of means for the production of the oriental porcelain.

Böttger himself, having probably some misgivings as to his eventual success in the fabrication of gold, was the more ready to give ear to the counsels and suggestions of Tschirnhausen, and was soon brought to cooperate with that person, and to deliver himself with all his characteristic ardour to a series of experiments on the fabrication of an improved pottery.

13. In order to remove them more effectually from popular interference and observation, the Elector had established Böttger and Tschirnhausen in the château of Albrechtsburg at Meissen. They were there abundantly supplied with artisans to work under them, and with all that was necessary for a porcelain laboratory and workshop. Böttger was liberally afforded all that could render life agreeable, except liberty. A carriage was provided for him, and he was allowed to visit Dresden and the neighbourhood at his pleasure, but an officer always accompanied him, never for a moment losing sight of him, lest he should escape, carrying with him his inestimable secrets.

The first result of their labours, which were still prosecuted under the strict surveillance of government, was merely the production of articles of earthenware, composed of a red and compact paste, differing, however, in nothing which was essential from the pottery of Spain, Italy, and France.

In 1706, the King of Sweden, Charles XII., entering Saxony, the King of Poland, Elector of Saxony, fearing that Böttger should be seized and carried away with his secrets, had him conducted with Tschirnhausen and three principal artisans, Ritter, Romanns, and Beichling, to the fortress of Konigstein, where they were strictly imprisoned, but supplied with a laboratory, where they were allowed to prosecute ther labours under rigid surveillance. Böttger is related to have lost none of his gaiety and animal spirits here. He amused his leisure hours and those of his companions in captivity in various ways, and among others, by the composition and recitation of verses.

Notwithstanding all the precautions which were observed for their safe keeping, Ritter and the others managed to form a plan of escape.

14. In 1707, after remaining a year at Konigstein, Böttger and Tschirnhausen were reconducted to Dresden, and established in a new laboratory which had been prepared for them on the Jungferbastei. Here they continued to prosecute their labours, all their researches being directed still to the discovery of the means of producing a pottery such as that which came from China. Their labours were incessant, and their spirit indefatigable; and it is related as an example of the untiring spirit of Böttger, that when it was considered necessary to watch the oven day and night for three or four successive days, he never left them himself, and kept his assistants awake by his inexhaustible fund of anecdote, and the gay and frequent sallies of his conversation.

It was said, that at this time some of the firing processes which required a more intense heat than could be obtained by the furnaces then in use, were effected by means of the solar rays collected in the focus of a large burning mirror, constructed by Tschirnhausen.

Tschirnhausen died the next year, 1708. This event, however, did not interrupt the course of experiments. Large ovens were erected, and batches of earthenware were exposed in them to the effect of the furnaces, often for five consecutive days and nights, producing successful results so far as the nature of the clays used permitted. The king, wishing to witness one of these experiments, they drew from the oven, in his presence, a tea-pot, still red-hot, which, being plunged in water, sustained the sudden change of temperature without injury.

15. The pottery thus produced was still, however, only a good stone-ware, with a red body, to which the brilliancy of porcelain was attempted to be imparted, either by polishing it on the wheel of a lapidary, or by covering it with an opaque-coloured glaze, which was vitrified at a comparatively low temperature.

At length, however, chance brought to Böttger a knowledge of the constituents of the true oriental porcelain, so long and so vainly sought for.

16. About this time, John Schnorr, one of the most wealthy and extensive iron-masters of Erzgebirge, happened to pass on horseback near AUE, where he observed the action of his horse to be impeded by reason of his feet sticking in a sort of white, soft, and tenacious earth, which lay upon the road, and which evidently formed the superficial stratum of the ground at that place. At that time, the use of hair-powder was universal, and that article formed consequently an object of commerce of capital importance. Engaged largely himself in commercial speculations, and endowed with an enterprising genius and quick sagacity, Schnorr conceived the idea of submitting this white clay to experiment, for the purpose of purifying it, and reducing it to a fine powder, which might find a profitable market as hair-powder, thus displacing the powder produced from wheaten flour.

Schnorr realised this project with complete success, and after a series of experiments made at Carlsfeld, established a manufactory of it, and soon found an extensive market and large demand for the article at Dresden, Leipsic, Zittau, and, in short, in all the German towns, where the new powder was known under the name of SCHNORR's WHITE EARTH.

17. Böttger, like all others of that day, wearing powder, he happened, while Klunker, his valet, was occupied in dressing his hair, to take in his hand a packet of the powder which he was using, and being struck with its extraordinary weight, greatly

exceeding that of powder made from flour, he asked Klunker where he bought it, and what it was called. Being informed that it was "Schnorr's White Earth," the idea instantly occurred to him that a clay so beautifully white, and admitting of pulverisation so infinitely fine, would serve as a material for fabricating an improved pottery; he instantly ordered a quantity of it to be procured sufficient for an experiment, which was no sooner tried than its precious qualities became conspicuously apparent. It was, in fact, the true kaolin, the very material of which the so highly-prized oriental porcelain was formed, and for which so many and such fruitless searches had been made in all parts of Europe.

18. The king now proceeded to establish the Royal Manufactory of Porcelain, which has since attained such universal celebrity. The Château of Albrechtsburg, at Meissen, was assigned to it, and Böttger was appointed its director.

The most rigid precautions were adopted to prevent the discovery, or its consequences, passing out of the country. The exportation of the "white earth" was interdicted under the most severe penalties, and it was transported from Aue to the manufactory at Meissen in sealed barrels, under military escort, and in the care of sworn keepers.

The precautions to ensure the secresy of the processes exceeded all belief. The precept solemnly inculcated into all who were employed in the manufactory, from the director to the lowest labourer, was "SECRESY TILL DEATH!" An oath to this effect was solemnly administered monthly to all the foremen and principal artisans, and was painted in conspicuous characters on the doors of all the workshops.

Whoever should be detected in disclosing any of the secrets of the processes was menaced by the royal ordinances with imprisonment for life in the fortress of Königstein.

19. In a word, the royal manufactory of Meissen was placed under the rigorous conditions of a fortress, the drawbridge never being lowered except at night. No one was admitted within its walls except those employed in the works; and even when the king brought foreigners of distinction to view the works, the processes were carefully concealed from them.

20. So late as the year 1812, M. Brongniart, then director of the Royal Manufactory of Sèvres, was sent by the Emperor Napoleon to inspect the porcelain works of Germany, and among others he visited those of Meissen. Even then the same rigorous system of secresy and exclusion was maintained. The King of Saxony, at the personal request of Napoleon, permitted M. Brongniart to see the works; but in order to do so, he was obliged to absolve M. Kuhn, the director, from his oath of exclusion. He did so,

as far as related to M. Brongniart individually, but he refused to include in the admission the associate who accompanied him.

The fine hard porcelain was now manufactured at Meissen, the colours, forms, painting and gilding of the oriental porcelain being so perfectly re-produced, that on examining the specimens of this early date preserved in the Dresden collection, M. Brongniart affirmed that he was only able to ascertain that they were not genuine Chinese porcelain by the mark of the Meissen manufactory impressed on them.

21. Böttger was unable to bear his elevation. Intoxicated with success, and supplied with pecuniary resources beyond his habits, he fell into a course of dissipation, and died in 1719, at the early age of thirty-five.

Such was the origin of the manufactory of porcelain at Dresden, which has since obtained a world-wide celebrity, and the source from which Europe for more than a hundred years obtained the most admired productions of the ceramic art.

22. The kaolin of Aue, discovered by the accidental circumstances above stated, continued, and still continues, to be used as one of the materials of the Saxon porcelain. Two sorts of paste are at present used in this manufacture. What is called the service paste, or that used for porcelain in general, is thus composed:

Kaolin of Aue	18
Kaolin of Sosa	18
Kaolin of Seidlitz	36
Feldspar, &c.	8
	100

For the statuary porcelain the feldspar of Carlsbad and quartz are mixed with the kaolin of Aue.

The manufacture of fine porcelain being thus established in Saxony, it soon spread to other parts of Europe, partly by the treachery and desertion of the parties engaged in the Meissen manufactory, and partly by the invention of other materials for the paste; and, in fine, by the discovery of strata of kaolin in other localities.

23. The style of the Dresden porcelain is familiar to all amateurs, and, whatever difference of opinion may prevail as to its taste, there can be none as to the admirable excellence of its execution. All who have visited the collection at Dresden, will be familiar with the series of animals, represented on a scale approaching to the natural size, including bears, rhinoceroses, vultures, peacocks, &c., made for the grand staircase which conducts to the electoral library. These were fabricated as early as 1730. At a later

period, when the manufacture had undergone improvements, large ornamental pieces of porcelain were made, such as the slabs of consoles and tables, some of which measure from 45 to 50 inches by 25, and are richly decorated with flowers.

24. Among the varieties of Dresden porcelain the grotesque figures and groups have always been much admired for their execution, if not for their style. The costumes are especially admirable, and the representation of fine work, such as lace, truly wonderful. One of the grotesque pieces which has attained most celebrity, and is familiar to all amateurs, is the famous tailor of the Count de Bruhl, a figure which is remarkable for the difficulty of its execution owing to the numerous accessories which it includes. The figure of the tailor is represented riding on a goat surrounded with all the implements and appendages of his trade, and is about 20 inches in height. This celebrated group was composed by Kundler in 1760, and is usually sold for about 12*l.*

The Dresden manufacture has always been remarkable for its representation of flowers; and a beautiful specimen of this work was seen in the Great Exhibition in 1851, consisting of a *camellia iaponica* with leaves and white flowers in porcelain, in a gilt pot, on a stand of white and gold porcelain. This article is priced at 90*l.*

25. The efforts made to conceal the important discovery thus made, and to monopolise the manufacture of fine porcelain at Dresden, were ineffectual. The force of interest proved more powerful than the respect for oaths, and the art, as improved in Saxony, soon spread to other parts of Germany.

One of the foremen of Meissen, named Stobzel, had deserted from that establishment about the year 1718, and escaped to Vienna, where, aided by a Belgian named Pasquier, and favoured by a privilege, or a sort of monopoly, for twenty-five years, granted to him by the Emperor Charles VI., he established, in 1720, a small porcelain manufactory. Not having, however, sufficient capital to carry it on, it declined, and was finally purchased by the Empress Maria Theresa in 1744, and erected into a royal manufactory. During nearly twenty years it required considerable subsidies for its support, but at length, by good management, it became profitable in 1760, and in 1780 yielded an annual profit of about 4000*l.* The number of operatives who were lately employed in this factory was about 400. The kaolin or porcelain clay used in this factory, until 1812, was obtained from the neighbourhood of Passau, on the confines of Bavaria, and from Prinzdorf, in Hungary. Lately, however, it has been supplied by clay obtained from the neighbourhood of Brün, in Moravia, and Unghbar, in Hungary.

As deserters from Meissen were instrumental in establishing the manufactory of porcelain at Vienna, deserters from Vienna soon spread the knowledge of the art to a greater or less extent in other parts of Germany.

26. Ringler, one of those who had originally deserted from Meissen, again breaking his engagements, and disregarding his oaths, left Vienna, taking with him plans of the ovens, and associating himself with M. Gelz, a manufacturer of earthenware at Höchst, near Francfort-on-the-Maine, he enabled that potter, with the aid of Lowenfink and Bengraf, two others, to establish the manufacture of the fine porcelain.

The German princes, captivated by the productions of this art, and ambitious, each in his own state, to establish a royal manufactory, in imitation of those of Dresden and Vienna, left no means of corruption and seduction untried to attract the potters, or even the subordinate workmen, who were engaged in the manufactories already established. Thus, the Duke of Brunswick endeavoured, by highly advantageous offers, to tempt the potter Bengraf to desert his employer, and succeeded, though not without much delay and many difficulties, for Bengraf was arrested by order of the Elector of Mentz, and was kept without food, until he was compelled to leave with his employer the full details of his processes, and to verify their exactitude. At length he was permitted to depart, and, in fine, he founded, in 1750, the well-known manufactory of Furstenberg, on the Weser. But as he died before his processes were carried into practical effect, the Duke of Brunswick failed in his object, and lost the expense he had incurred. He resorted in vain to the aid of an eminent chemist of that day, the Baron de Lang, to find means of realising the plans of Bengraf.

Ringler having remained at Höchst, continued to direct the processes of that manufactory, taking care, however, to conceal his processes, so that without his personal superintendence the works could not proceed. Being addicted to drinking, his companions, availing themselves of his infirmity, and knowing that he usually carried on his person receipts for his processes, tempted him into an excessive indulgence in wine, which ended in his falling into a state of insensibility. Availing themselves of this, they rifled him of his papers, and his receipts being copied and re-copied, were carried about the German States, and sold for considerable sums to wealthy persons, who considered themselves fortunate in becoming the possessors of the processes of an art so much and so universally admired.

27. Among these hawkers of Ringler's receipts or notes, one of the most noted and active was a certain Paul Becker, who, after

travelling through France and the Netherlands, at length settled in Brunswick, where he received a pension from the Duke, on the condition of ceasing from his peregrinations. Most of the notes and receipts which were thus put in circulation, were either garbled and fragmentary, or altogether spurious, so that little or no practical advantage was derived by those who became their possessors.

Ringler quitting Höchst, went to Frankenthal, where, associating himself with a merchant, named Hammung, he established a porcelain factory, which afterwards became one of the best known in Germany.

28. He went to Munich, where he established, under the protection of the King of Bavaria, the royal porcelain-works at Nymphenburg, within a few miles of the city, in 1758.

This establishment still continues, and is now the Royal porcelain manufactory of Bavaria. The white biscuit is manufactured at Nymphenburg, and its ornamentation effected in workshops at Munich. The porcelain clay used in this manufactory is obtained near Passau, already mentioned, the felspar from Raberstein, in Bavaria, and the quartz from Abensburg, near Ratisbon. It was, in like manner, by means of information brought by deserters and runaways from factory to factory, that the fabrication of porcelain came to be established successively in the royal manufactories of Louisberg near Stuttgard, at Berlin, Copenhagen, Brunswick, and St. Petersburgh.

After the peace of Hubertsburgh, Frederick II. of Prussia, erected the royal manufactory of Berlin. While he was master of Dresden, he sent a considerable quantity of the porcelain clay of Meissen, and several of the operatives of this factory, to Berlin, to aid in the establishment of the manufactory in that city.

29. Chance, which played so remarkable a part in the progress of the ceramic art elsewhere, was also the origin of its establishment in the Thuringen.

In 1758, an old woman brought to the laboratory of the chemist Macheleid, a powder, which she proposed to be used as sand for drying writing. The grain and colour of this powder struck Henry Macheleid, the son of the chemist, who had studied at Jena, as bearing a resemblance to china clay. He submitted it to analysis, and found that it was kaolin. In fine, he succeeded in making porcelain with it, and founded in 1762 a manufactory of that article at Sitzerode, which in 1767 was transferred to Volkstadt, and became the origin of all the other manufactories of that district of the German states.

30. While the art made this progress in Germany, the French potters failing to discover either a true kaolin or any other clay

having the qualities necessary to render it a tolerable substitute for the fine china clay, directed all their efforts to invent some artificial composition which might serve the purpose and enable them to compete with foreign potters.

The result was the invention of an artificial imitation of the porcelain paste, which soon became the basis of a great manufactory in France, and which continued for half a century to be known as the *pâte tendre* of the Royal manufactory of Sèvres.

This material did not contain a particle of kaolin or felspar, the essential constituents of all genuine porcelain. Its composition was subject from time to time to slight variations; for, for the best porcelain, it consisted of the following constituents in an hundred parts by weight:—

Fused nitre (mineral crystals)	22·0
Grey sea-salt	7·2
Alum	3·6
Soda of Alicant	3·6
Gypsum of Montmartre (plaster of Paris)	3·6
Sand of Fontainbleau	60·0
	100·0

These materials being well mixed, were fritted either in the porcelain oven, or in an oven expressly appropriated to this process. It was usual, however, to calcine the alum and the gypsum previously to disengaging their water of crystallisation.

The dough called the *pâte tendre,* was formed by the mixture of this frit with white chalk and calcareous marls from the gypseous earth of Argenteuil, in the following proportions by weight:—

Frit	75
Chalk	17
Gypseous earth	8
	100

The whiteness and consistency or hardness of this dough was modified by varying the proportion of chalk.

All these materials were intimately kneaded together, bruised with water in a mill, and in fine passed through silken sieves.

The glaze used for this factitious biscuit was composed as follows:—

Litharge	38
Calcined sand of Fontainbleau	27
Calcined silex	11
Sub-carbonate of potash	15
Sub-carbonate of soda	9
	100

31. This paste after all was so utterly wanting in plasticity and

consistency that it could not be worked on the potter's wheel, and was even moulded not without much difficulty.

To give it sufficient tenacity and consistency to prevent it from cracking or crumbling to pieces in the process of moulding, it was mixed with about twelve per cent. of its own weight of a mixture of black soap and parchment size, the soap at a later period being replaced by a solution of tragacanth gum, to which are attributed the saline efflorescences which were occasionally manifested on the articles fabricated. In the process of turning the moulded pieces a saline and silicious dust was produced, which was extremely injurious to the potters, and caused asthmatic and pulmonary complaints. This was one of the reasons why the fabrication of tender porcelain was the more readily discontinued after the discovery of kaolin.

Owing to the want of plasticity and coherence in this artificial paste, great difficulties were encountered in the several stages of its manufacture. The want of tenacity rendered it necessary, when the articles were placed in the oven, to support all the projecting parts during the process of baking; and, in order that the forms of these parts might not be distorted, it was necessary that their supports should be formed of the same paste as the articles themselves, so that the whole mass, including the supports, might contract together. The linear dimensions contracted in the baking by one-seventh, and, consequently, the bulk or volume of the article was diminished in the proportion of three to two.

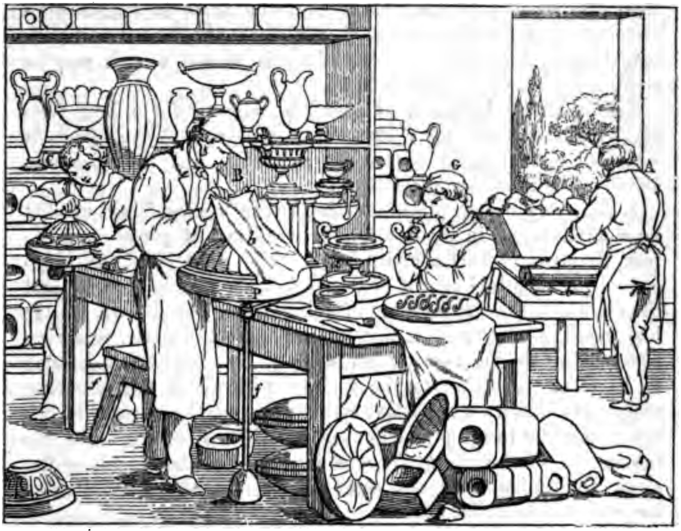


Fig. 35.—MOULDER'S SHOP IN PORCELAIN WORKS.

THE POTTER'S ART.

CHAPTER IV.

1. Meaning of the epithet "tender" as applied to porcelain.—2. Qualities and value of this porcelain.—3. Art of making it not lost.—4. Origin of the Sèvres manufactory.—5. Efforts to discover kaolin—Paul Hannong.—6. Kaolin of Limoges discovered.—7. Anecdote of Madame Darnet.—8. English porcelain at Bow, Derby, and Worcester.—9. Cornish china clay.—10. Properties of true porcelain.—11. Stoneware.—12. Cause of translucency.—13. Hard and tender porcelain distinguished.—14. English tender porcelain.—15. Mode of preparing the clay.—16. Statuary porcelain.—17. Process of its fabrication.—18. Process of producing colours on porcelain.—19. Coloured figures on common ware; press and bat printing.—20. Distinctive marks of the manufactories—21. Various recent applications of the art.

1. The epithet *tender*, applied to this porcelain, must not be understood as implying the quality of softness. It is intended, on the other hand, to express two qualities by which it is distinguished

from the hard porcelain: first, that the paste is fusible at a certain temperature lower than that at which the hard porcelain is baked; and, secondly, that the glaze is so soft that it may be scratched with a steel fork or knife.

This artificial imitation of porcelain enjoyed for a long time great celebrity; and after its manufacture was discontinued, it was still more eagerly sought by amateurs, and its price was enhanced by its comparative scarcity.

2. The very defects of this artificial porcelain conferred upon it some advantages, in its decoration, over the real porcelain made from the paste of kaolin and felspar. The softness of the glaze caused painting laid over it to penetrate more or less into it, and thus to assume the appearance of being incorporated with it. It had the same effect as if it were placed under the glaze, retaining nevertheless the most perfect brilliancy. This is an effect difficult to be attained, owing to the facility with which the colouring matter is affected by the saline constituents of the glaze. It has not reappeared in the productions of the Sèvres factory since the fabrication of the *pâte tendre* was discontinued there. Since the great Exhibition, however, some of the British manufacturers have produced similar effects.

There are certain coloured grounds which are eminently characteristic of the old Sèvres porcelain, the proper porcelain paste not being in the same degree susceptible of receiving them. These are the beautiful light blue called TURQUOISE, from its resemblance to the colour of the stone of that name, the GROS BLEU, the GREEN obtained from copper, and the red distinguished as the ROSE DUBARRY, from the preference shewn to it by the notorious mistress of Louis XV.

Although this factitious ware contained no portion of either of the essential constituents of true porcelain, and ought not, therefore, ever to have received the name, or to be regarded as anything else than a spurious imitation of that admired production of Art; it must at the same time be admitted to be, in its superficial and external qualities, a beautiful copy of a beautiful original, and to require in its preparation and fabrication much more profound resources of science and art than what is composed chiefly of matters which nature presents nearly in the state in which they enter into the composition of the article fabricated. To discover and fitly combine the complicated elements of this artificial porcelain required patient research, great chemical skill, much sagacity, perseverance, and genius; while the casual discovery of a vein of kaolin and felspar would have at once enabled any potter, already master of his art, to fabricate the genuine porcelain.

The fabrication of this celebrated pottery commenced in France about the year 1695, and was continued for more than a century. The existence of true kaolin in France was not discovered until 1768, when the manufacture of real porcelain was commenced, and was prosecuted concurrently with the fictitious porcelain until 1804, when the fabrication of the latter was discontinued; and since that time the real porcelain only has been produced in the French Royal Manufactory.

3. Among amateurs in porcelain, including even those who are otherwise well-informed, there prevails a notion that the art of fabricating the tender porcelain of Sèvres has been lost, and that, since it is impossible to reproduce the articles, they must necessarily have a high value in the market. This, however, is erroneous. All the materials and processes for the fabrication of this description of artificial porcelain are preserved at Sévres, and the manufacture can be re-established whenever it is desired to do so. Indeed, we are informed that the Administration entertains an intention of recommencing the fabrication of this description of porcelain for articles of ornament, such as vases, pictures, &c., the imperfections incidental to it not affecting such objects.

In 1695, when the first attempt at the fabrication of the *pâte tendre* was made, the porcelain works at St. Cloud were the property of a private individual named Morin. The invention of this artificial paste was the result of twenty-five years of labour and research. It appears, therefore, that this manufacture commenced about fifteen years before the discovery of kaolin, and the commencement of the fabrication of hard or real porcelain at Dresden.

4. The establishment which has since attained such celebrity as the Royal Sèvres Porcelain Works, was previously established at Vincennes, where it was first conducted as a private enterprise. In 1753, Louis XV. became joint-proprietor of it, taking a third share, and gave it the sanction of royal protection, and the title of the Royal Manufacture of Porcelain. Having attained, about 1754, great celebrity from the extraordinary perfection and beauty of its productions, and especially for a magnificent service presented by the king to the Empress Catherine of Russia, the manufacture enlarging its works, the buildings at Vincennes were found to be too confined for its more extended operations: and a site having been obtained at the village of Sèvres, on the highroad from Paris to Versailles, a building on a vast scale was erected there for the manufacture, which was removed there in 1756.

A few years later, in 1760, the king purchased the interests of the other proprietors, and the works became, and have ever since continued to be, the exclusive property of the Government.

5. It may be easily imagined that the celebrity of the German porcelain, and more especially that of Dresden, excited the most lively desire, and the most unceasing endeavours, to discover in France the precious mineral which alone formed the base of the genuine article. It was necessary, however, first to ascertain what the actual material was, which still remained to a great extent a secret; and next to discover where, if at all, it could be obtained in France.

In 1753, just before the removal of the Royal Manufactory from Vincennes to Sèvres, Paul Hannong, a citizen of Strasburg, who was proprietor of earthenware and porcelain works at Hagenau, being in possession of the full knowledge of the materials and processes of the German porcelain manufacture, proposed to M. Boileau, director of the manufactory at Vincennes, to sell to that establishment the secret of the manufacture, for which he demanded 4000*l*. in cash, and a life annuity of 480*l*. This proposal being declined, a royal decree in 1754 prohibited him from carrying on his works in France, and he accordingly established them at Frankenthal.

Paul Hannong died and was succeeded by his brother Pierre Antoine, with whom the French Government re-opened the negotiations which had been broken off by reason of the exorbitant demands of Paul. A greater facility now appearing to be manifested, the ministers of Louis XV. spared no exertion to secure to France the possession of an art so highly esteemed, and to rescue the country from the necessity of obtaining only by importation articles so highly prized. M. Boileau, the director of the royal works at Sèvres, was sent to Frankenthal with full powers, and the result of his negotiation was a contract signed on the 29th July, 1761, by which Pierre Antoine Hannong engaged to make known all the processes and the materials for manufacturing the true porcelain. Eventually, however, the execution of this contract to the advantage of the French government was rendered impossible by the fact, not foreseen, that the raw materials, kaolin and felspar, indispensable for the fabrication of the porcelain, not having been discovered in France, could only be obtained from countries where their exportation was prohibited. Under these circumstances the contract with Hannong was dissolved, the Government, however, granting him as compensation a sum of 160*l*. and a life annuity of 48*l*.

6. The time, however, had now arrived when chance was destined to do for the porcelain manufacture in France what it had done elsewhere, by leading to the discovery of kaolin.

Madame Darnet, the wife of a village surgeon, residing at St. Yrieix, near Limoges, accidentally found in a valley in the neighbourhood of that town a white unctuous earth, which she regarded as being capable of being rendered useful in the washing of linen. With this purpose she showed it to her husband, who, better informed, suspected other and more valuable properties in it, and undertook a journey to Bordeaux to submit it to a chemist of that place, named Villaris. This person, who had been already informed of the qualities necessary for porcelain clay, and of the eagerness with which it was sought for, suspected that the specimen brought to him by M. Darnet possessed these qualities. It was accordingly sent to Macquer, the chemist at Paris, who was then occupied in experiments on the improvement of porcelain. He immediately recognised in this specimen of clay the true kaolin, and went to St. Yrieix in August 1768, where he found a large vein of this precious material. Experiments were made upon it upon a considerable scale at Sèvres, where all doubts upon the subject were soon removed; and the kaolin of St. Yrieix near Limoges was immediately adopted as the material, and the fabrication of the hard porcelain was commenced.

7. M. Brongniart relates a curious and interesting anecdote connected with this subject. He says that, in 1825, being at Sèvres, where he was still director, an aged woman addressed herself to him one day supplicating temporary relief, and apparently suffering from extreme want. She asked for aid to enable her to return on foot to St. Yrieix, whence she had come. This woman was Madame Darnet, the discoverer of the kaolin of Limoges. The relief she sought was immediately given to her; and, on the application of M. Brongniart, Louis XVIII. granted her a small pension on the civil list, which she enjoyed till her death.

8. The first English porcelain was manufactured at Bow and Chelsea, near London, the paste being composed of a mixture of the sand from Alum Bay, in the Isle of Wight, with a plastic clay and powdered flint glass; this was covered with a leaden glaze. This manufactory had considerable success.

In 1748, the manufacture was transferred to Derby; and in 1751, Dr. Wale established at Worcester a manufactory of tender porcelain, called the "Worcester Porcelain Company," which still exists, though in other hands. To Dr. Wale is attributed the invention of printing on porcelain, by the transferring of printed patterns from paper to the biscuit. The proposed design is first engraved on copper, and the colouring matter being applied to the engraving in the same manner as in common copper-plate printing, the design is transferred to paper. This paper is afterwards applied to the biscuit, to which the colouring matter forming the design adheres. The paper is then dissolved and washed off, the colouring matter forming the design remaining upon the biscuit. The biscuit is then glazed over the design with a glass glaze, so that after vitrification the design appears under the glass.

The original Worcester Porcelain Company principally limited their business to the manufacture of blue and white porcelain, in imitation of that of Nankin, and making the Japanese pottery. Cookworthy, of Plymouth, continued to carry on the porcelain business at Worcester until 1783, when the manufactory fell into the hands of Mr. Thomas Flight.

9. About 1751, Messrs. Littler, Yates, and Baddeley attempted the same manufacture in Staffordshire, but without success, and it was not until 1765 that Messrs. Baddeley and Fletcher succeeded in the manufacture of porcelain at Shelton.

The kaolin or china clay, as it is usually called, which is used in the manufacture of British porcelain, is found in the counties of Cornwall, Devon, and Dorset. That of Cornwall was discovered about the same time as that of the discovery of the kaolin of St. Yrieix, in 1768, by Cookworthy. This is the most esteemed, and its introduction into the manufacture of porcelain gave a great impulse to the art.

10. The qualities by which porcelain is distinguished from the inferior productions of the potter are, density, whiteness, transparency, and fine texture of the glaze. These properties are estimated in the order wherein they are here enumerated, compactness of body being the point which it is considered most desirable to attain. The glaze, as seen in the finished porcelain, should not put on a lustrous appearance; but while beautifully smooth to the touch, should present to the eye rather the softness of velvet than the gloss of satin. This peculiar semblance will only be produced with glaze that melts with difficulty, and when the heat has been raised precisely to, and not beyond, the point that is necessary for its fusion.

11. Stoneware is a very perfect kind of pottery, and approaches nearer than any other description to the character of porcelain. Its body is exceedingly dense and compact, so much so, indeed, that although vessels formed of it are usually glazed, this covering is given to them more with the view of imparting an attractive appearance than of preserving them from the action of liquids. When properly made and baked, stoneware is sufficiently hard to strike fire from a flint, and is as durable as porcelain.

12. The translucency of porcelain arises from the vitrification of one of the constituents of the paste in the process of baking. The other constituents being much more refractory, the article still

retains its form, just as a porous vessel such as a flower-pot would, if it were thoroughly saturated with water. The semi-transparency of porcelain thus produced is an effect of the same class as that imparted to paper or linen cloth by saturating it with melted wax. The vitrifiable constituent which thus renders porcelain translucent is generally the felspar; in some cases, however, it is lime which, entering into combination with the alumina and silica of the clay, forms a double silicate of alumina and lime, more fusible still than the simple silicate of alumina. The oxide of iron produces a like effect, but as it gives a colour to the paste, it can only be used in the commoner sorts of ware. By increasing the proportion of the vitrifiable constituent, greater translucency is imparted to the ware, but the body becomes less plastic, more liable to distortion, and more difficult to work.

13. It is most necessary to comprehend the distinction between the hard porcelain, the manufacture of which, as we have stated, was carried on at a very early date in the East, and the varieties of tender porcelain. The body of the latter sorts is more fusible than that of the former. This property is given to it by introducing into it a larger proportion of alkaline constituents, either in the form of felspar, or of alkaline silicate, prepared expressly for the purpose, and called *frits*. The glaze used for these porcelains is also more fusible than that of hard porcelain, a quality which it receives from a certain proportion of the oxide of lead which enters into its composition.

In certain sorts of tender porcelain no clay whatever is used, and the entire body consists of an artificial *frit*. Such ware, however beautiful it may be rendered in external form and appearance by fine workmanship and rich ornamentation, cannot properly be called porcelain at all. It is at best only an ingenious imitation of that article, bearing to it the same relation as a gilded article bears to a gold one. Nevertheless, such is the article so much admired and so highly prized under the denomination of the "Old Sèvres Porcelain."

14. The English porcelain, and certain sorts still produced in some of the private manufactories of France, belong to the class of tender porcelain, though not all identical with, or even resembling, the Old Sèvres Porcelain. The English porcelain is composed chiefly of clays found in Cornwall, Devon, and Dorsetshire. The Cornish is the best quality, and is technically termed by potters "china clay;" it enters very extensively into the composition of the best kind of ware. It is the decomposed felspar of the granite, and is prepared by the clay merchants themselves in Cornwall, prior to its being sent to the potteries. Huge masses of white granite abound in Cornwall, which is in some parts found partially decomposed;

and when this is the case, the mineral is raised and prepared for the potter's use.

15. The following is the method of preparation:—The stone, having been broken by a pickaxe, is laid in a stream of running water: the light argillaceous parts are thus washed off and kept in suspension; the quartz and mica being separated are allowed to subside near the place where the stone was first raised. At the end of these rivulets are a kind of catchpools, where the water is at last arrested, and time allowed for the pure clay with which it is charged to form a deposit, which, being effected, the water is drawn off; the clay is then dug up in square blocks and placed upon a number of strong shelves, called "linnees," so fitted as to allow of the free circulation of air, that the clay may be properly dried. Thus prepared, it is an extremely white mass, capable by being crushed to be reduced to a fine impalpable powder. In this state it is sent to the potteries under the name of China clay.

16. One of the departments of this manufacture, in which England has of late years gone considerably in advance of the continent, is that devoted to the fabrication of statuary porcelain. This beautiful branch of reproductive art has been almost created within the last six or seven years by some of the most eminent and enterprising establishments in Staffordshire.

Like all novelties in the arts, this process has undergone a succession of improving changes. At first the statuary material was limited to a thin superficial coating laid upon a common body. At present, however, the object is composed of one homogeneous mass of statuary porcelain. The articles thus produced are superior in quality, but much more difficult of manufacture, owing to the much greater degree of contraction which takes place in the oven, and the consequently increased chances of distortion and fracture, especially in pieces of complex form and considerable magnitude. The contraction of the linear dimensions amounts to as much as a fourth of the original magnitude, so that a figure, which as moulded or cast is four feet high, comes out of the oven definitively only three feet in height, the other dimensions being decreased proportionally. The actual contraction in the cubical dimensions which corresponds to this is more than one half, so that the baked materials are included in less than half the space occupied by the unbaked.

17. The process by which statuary porcelain is produced is that called casting, and it resembles in many respects that by which casts of objects are produced in metal.

If the object to be produced is such as can be cast in a single piece, a mould of its form is made in plaster of Paris, consisting of two parts which can be united by perfectly plane and smooth surfaces, each part having a sunk impression of one side of the intended object. A clear enough notion of such a mould may be obtained from a common bullet-mould.

When the two parts of the mould are brought into contact, it will leave within it a hollow space corresponding exactly in form with the intended figure, but having a small opening through which the liquid may be introduced.

The statuary paste is brought, by mixture with about its own weight of water, to the consistency of a thick cream, and being well and carefully mixed, so as to be quite homogeneous, it is poured into the mould, which is kept full of it for a certain time, more or less according to the thickness which it is desired to give to the statuary material composing the object. While it thus stands, the bibulous quality of the plaster mould causes it to imbibe water from that portion of the creamy liquid or "slip," as it is called, which is in contact with it, so that a coating of paste, in a sufficiently dry state to have coherence, remains attached to the surface of the mould. Within this is contained that portion of the slip which still remains in the liquid state. This being discharged through a small hole in the mould, provided for that purpose, the mould remains lined with a solid coating of the porcelain paste of a certain thickness.

If it be desired to render the coating upon the mould thicker, so as to give greater strength and weight to the object moulded, the process is repeated; and, in order to equalise the thickness of the deposit, the mould, if it be not too large, is reversed in its position each time that it receives a new charge of slip.

When the mould, by this process, has received a coating of sufficient thickness it is opened, and the object thus cast taken out of it; which is easily accomplished, since no adhesion takes place between its surface and that of the mould.

The thickness of the article thus formed may be varied within practical limits, from that of the egg-shell to the thickness required by objects of the largest attainable dimensions. A beautiful application of this process is practised in the continental factories, by which a thin, delicate article is produced, called egg-shell porcelain.

When a large figure, or group of figures, is to be produced, the process is more complex. Let us suppose its height in the model to be twenty-four inches. Separate and independent moulds are previously made for various parts of the piece, and in the larger and more complex subjects the number of these sometimes amounts to forty or fifty.

Supposing the figure or group to measure twenty-four inches in height as moulded, the shrinking that occurs before these casts can be taken out of the mould, which is caused by the absorbent nature of the plaster of which the mould is composed, is equal to a reduction of one inch and a half in the height. These casts are then put together by the "figure-maker;" the seams consequent upon the marks caused by the subdivisions of the moulds being carefully removed, the whole is worked upon to restore the cast to the same degree of finish as the original model. The work is then thoroughly dried, to be in a fit state for firing, since, if it were put in the oven while damp, the sudden contraction consequent upon the great degree of heat to which it would be suddenly exposed, would be very liable to cause it to crack: in this process it again suffers a further loss of one inch and a half by evaporation, and it is now but twenty-one inches high. Again, in the "firing" of the bisque oven, its most severe ordeal, it is diminished three inches, and is then but eighteen inches high, being six inches or one-fourth less than the original. It loses, therefore, in the entire process, one-fourth of its linear, and therefore more than one-half of its cubical dimensions. Nevertheless, such is the consummate skill brought to bear on this beautiful manufacture, that in good specimens there is not the slightest discoverable distortion or defect of form or outline.

The perfection to which this branch of the potter's art has recently attained, is such as to render it probable that it will eventually be to sculpture what engraving has been to painting, but with a much closer affinity, identity of colour and texture being attained, as well as that of outline and design.

18. The enamel colours used in the ornamentation of porcelain are produced by certain oxydes of the metals combined with other substances, called *fluxes*, which have the effect of facilitating their fusion. Thus the oxyde of gold produces tints of red, such as crimson, rose-red, and purple. Reds are also produced by the oxydes of iron and chrome. The same oxydes, as well as those of cobalt and manganese, produce blacks and browns; those of uranium, chrome, antimony, and iron produce orange; those of chrome, and copper, green; and those of cobalt and zinc, blue. The fluxes for these various oxydes are borax, flint, oxyde of lead, &c.

These colouring materials are worked up with essential oils and turpentine, and a very great disadvantage under which the artist labours is, that the tints upon the palette are in most cases different to those they assume when they have undergone the necessary heat, which not only brings out the true colour, but also by partially softening the glaze and the flux, causes the colour to become fixed to the ware. This disadvantage will be immediately apparent in the case where a peculiar delicacy of tint is required, as in flesh tones, for instance. But the difficulty does not end here, for, as a definite heat can alone give to a colour a perfect hue, and, as the colour is continually varying with the different stages of graduated heat, another risk is incurred—that resulting from the liability of its receiving the heat in a greater or less degree, termed "over-fired" and "short-fired." As an instance of its importance we will cite rose-colour, or crimson, which, when used by the painter, is a dirty violet or drab; during the process of firing it gradually varies with the increase of heat, from a brown to a dull reddish hue, and from that progressively to its proper tint. But if by want of judgment or inattention in the fireman, the heat is allowed to exceed that point, the beauty and brilliancy of the colour are destroyed beyond remedy, and it becomes a dull purple. On the other hand, should the fire be too slack, the colour is presented in one of its intermediate stages, as already described; but in this case extra heat will restore it. Nor must we forget to allude to the casualties of cracking and breaking in the kilns by the heat being increased or withdrawn too suddenly, a risk to which the larger articles are peculiarly liable. These vicissitudes render enamel painting in its higher branches a most unsatisfactory and disheartening study, and enhance the value of those productions which are really successful and meritorious.

In enamelling, ground-laying is the first process in operating on all designs to which it is applied; it is extremely simple, requiring principally lightness and delicacy of hand. A coat of boiled oil adapted to the purpose being laid upon the ware with a pencil, and afterwards levelled, or as it is technically termed "bossed," until the surface is perfectly uniform; as the deposit of more oil in one part than another would cause a proportionate increase of colour to adhere, and consequently produce a variation of tint. This being done, the colour, which is in a state of fine powder, is dusted on the oiled ground with cotton wool; a sufficient quantity readily attaches itself, and the superfluity is cleared off by the same medium. If it be requisite to preserve a panel ornament, or any object white upon the ground, an additional process is necessary, called "stencilling." The stencil (generally a mixture of rose-pink, sugar, and water) is laid on in the form desired with a pencil, so as entirely to protect the surface of the ware from the oil, and the process of "grounding," as previously described, ensues. It is then dried in an oven, to harden the oil and colour, and immersed in water, which penetrates to the stencil; and, softening, the sugar is then easily washed off, carrying with it any portion of colour or oil that may be upon it, and leaving the ware perfectly clean. It is sometimes necessary, where great depth of colour is required, to repeat these colours several times. The "ground-layers" do generally, and should always, work with a bandage over the mouth, to avoid inhaling the colour-dust, much of which is highly deleterious. Bossing is the term given to the process by which the level surfaces of various colours, so extensively introduced upon decorated porcelain, are effected. The "boss" is made of soft leather.

The process of gilding is as follows:—The gold (which is prepared with quicksilver and flux), when ready for use, appears a black dust; it is used with turpentine and oils similar to the enamel colours, and, like them, worked with the ordinary camel's-hair pencil. It flows very freely, and is equally adapted for producing broad massive bands and grounds, or the finest details of the most elaborate design.

To obviate the difficulty and expense of drawing the pattern on every piece of a service, when it is at all intricate, a "pounce" is used, and the outline dusted through with charcoal—a method which also secures uniformity of size and shape. Women are precluded from working at this branch of the business, though, from its simplicity and lightness, it would appear so well adapted for them. Firing restores the gold to its proper tint, which first assumes the character of "dead gold," its after brilliancy being the result of another process termed "burnishing." *

19. The ornamentation of the less costly descriptions of ware, such as are in common use for the table, and in which a single colour only is used, is accomplished by a process similar to that of copper-plate printing. There are two methods of effecting this, one called "press," and the other "bat" printing. In "press" printing the design is formed on the article before it receives the glaze, and is afterwards covered and protected by the glaze, through which, being quite transparent, it is visible. In "bat" printing, on the other hand, the design is laid upon the glaze, and fixed there by enamelling it.

In both cases the design is first executed on a copper-plate. For press printing it must be cut very deep to enable it to hold a sufficiency of colour to give a firm and full transfer on the ware. The printer's shop is furnished with a brisk stove, having an iron plate upon the top, immediately over the fire, for the convenience of warming the colour while being worked, also a roller, press, and tubs. The printer has two female assistants, called "transferrers," and also a girl, called a "cutter." The copper plate is charged with colour, mixed with thick boiled oil, by means of a knife and "dabber," while held on the hot stove plate, for the purpose of

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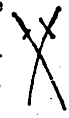
* Official Catalogue of the Great Exhibition, p. 713.

keeping the colour fluid; and the engraved portion being filled, the superfluous colour is scraped off the surface of the copper with the knife, which is further cleaned by being rubbed with a "boss," made of leather. A thick firm oil is required to keep the different parts of the design from flowing into a mass, or becoming confused, while under the pressure of the rubber in the process of transferring. A sheet of paper, of the necessary size and of a peculiarly thin texture, called "pottery tissue," after being saturated with a thin solution of soap and water, is placed upon the copper plate, and being put under the action of the press, the paper is carefully drawn off again, the engraving being placed on the stove, bringing with it the colours and design with which the plate was charged. The paper is then laid upon the ware, and rubbed upon it with flannel. During this friction the coloured design upon the paper is partly imbibed by the unglazed surface of the ware, and partly remains upon that surface. The article is then immersed in water, by which the paper being softened, and partially dissolved, it is easily washed off with a sponge, the coloured design alone remaining on the surface of the article. The oil included in the colouring matter is then expelled by exposure to heat in a kiln, called a hardening kiln, after which the design being left in perfectly dry colouring matter, the article is glazed. When covered with the raw glaze, the design is quite invisible, the glaze being opaque in that state; but when it is vitrified in the oven, it becomes quite transparent, and the design is apparent through it.

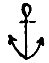
The bat printing is done upon the glaze, and the engravings are for this style exceedingly fine, and no greater depth is required than for ordinary book engravings. The impression is not submitted to the heat necessary for that in the bisque, and the medium of conveying it to the ware is also much purer. The copper plate is first charged with linseed oil, and cleaned off by hand, so that the engraved portion alone retains it. A preparation of glue being run upon flat dishes, about a quarter of an inch thick, is cut to the size required for the subject, and then pressed upon it, and being immediately removed, draws on its surface the oil with which the engraving was filled. The glue is then pressed upon the ware, with the oiled part next the glaze; and being again removed, the design remains, though, being in a pure oil, scarcely perceptible. Colour, finely ground, is then dusted upon it with cotton wool, and a sufficiency adhering to the oil leaves the impression perfect, and ready to be fired in the enamel kilns.

20. It has been the practice at all the great porcelain manufactories to stamp upon the bottom, or some other convenient

part not exposed to view, of each article fabricated, a peculiar distinctive mark, by which the place of its manufacture shall be always capable of being ascertained. It will not be without interest here to indicate some of the principal of these marks.

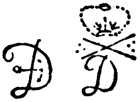


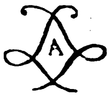
The Dresden porcelain, manufactured at the royal manufactory of Meissen, bears the mark of two swords crossed, as here represented.



The English porcelain, manufactured at the celebrated Chelsea works, is marked with an anchor, thus

The porcelain manufactured at Derby is marked with the cypher





The old Sèvres porcelain, fabricated from 19th Aug., 1753, until the fall of Royalty in 1793, is marked with the cypher

During the Republic, from 1793 until the end of 1800, the mark over the Sèvres porcelain was simply the initials F. R.

From 1800 to 1804 the articles were marked with the characters,

M . N^{le} (Manufacture Nationale).
Sèvres
— ″ =

During the Empire, 1804 to 1814, the words Manufacture Impériale, Sèvres, were stamped upon the porcelain.

From the Restoration to the Revolution of 1830, the articles bore the royal cipher, the double L or double C.

From 1830 to 1834, the symbol of equality, a double equilateral triangle was used: and from 1834 to the Revolution, 1848, the articles bore the cipher of Louis Philippe.

By these indications the amateur will be enabled to determine the epoch of the manufacture of such articles as may fall under his notice.

21. There is nothing more remarkable in this branch of industry than the great number and variety of unexpected uses to which the ingenuity of the manufacturer has rendered it subservient. At the Great Exhibition of 1851, this was especially conspicuous. Among the specimens there collected were found, for example, chimney-pieces of statuary porcelain. The advantages of this application are numerous and obvious. Among them are great durability and freedom from the susceptibility of discoloration and staining to which marble is liable. Plateaux and slabs for the covering of fire-places, tops of console toilet and chess-

tables, panels of doors and window-shutters, tiles for flooring and walls, terra-cotta for vases and garden pots, are among the many productions of this art.

Encaustic tiles for ornamental flooring merit especial notice. This branch of the earthenware manufacture has recently acquired considerable importance, and an export business of some extent has been already established in it. Large quantities of this article are now exported to the United States and the colonies, as well as to certain parts of Europe. The palace of the Sultan at Constantinople is paved with this tiling, as are also the House of Lords, Osborne House, and St. George's Hall, Liverpool. This flooring has got into very general use in churches, private mansions, conservatories, &c. It is as durable as marble, less liable to stains, and can be decorated with any design to suit the taste of the purchaser.

As a specimen of pottery on a large scale, the figure of Galatea, seven feet high, is deserving of attention. This claims to be the largest perfect object in pottery which has yet been produced in a single piece. Attempts are, we understand, being made, with some probability of success, to produce it in statuary porcelain.

Among the ornamental and merely artistic applications of this art, we must not omit to notice the copies of paintings, often upon a very large scale, made in enamel colours upon slabs of porcelain. These beautiful productions of the ceramic art proceed almost exclusively from the national manufactories of France and Saxony.

The portraits of the Queen and Prince Albert, which were exhibited in the great aisle of the Crystal Palace, are fine specimens of the largest porcelain paintings which have been produced at the Sèvres manufactory. These are half-length portraits of the size of life, each painted on a single slab of porcelain. They are copies of the well-known portraits by Winterhalter, and were executed by order of Louis Philippe, and presented to her Majesty. These works were commenced before the revolution of 1848, but not finished until after that event. Louis Philippe claimed them as his private property, and they were surrendered to him by the Republican Government; but the portrait of Prince Albert had met with an accident, by which it was broken. Louis Philippe desired to have another made, but the Queen would not hear of this expense being incurred; and the fracture being repaired at Sèvres, the portraits were sent to England and delivered to her Majesty. The portrait of her Majesty is by A. Ducluzeau, and that of Prince Albert by A. Bezanget.

Among the splendid collections of paintings and vases exhibited by the national manufactory of Sèvres, at the Great Exhibition, the most valuable and most worthy of attention and examination were the following:—

The painting of the Virgin, known as the *Vierge au Voile*, by Madame Ducluzeau, was copied from the celebrated picture by Raffaelle in the Louvre. The porcelain is of the same magnitude as the original, and measures 26 inches by 19. This work was executed in 1847-8, price 1000*l.* Another painting after Tintoretto, on a plate of porcelain 45 inches high, by Madame Ducluzeau, price 880*l.* A flower subject on a plate of porcelain, 40 inches high, by M. Jacober, 800*l.* A portrait of President Richardeau, by M. Beranger, 440*l.* A portrait of Vandyck, by Madame Ducluzeau, 280*l.* A painting on a plate of porcelain, eight inches high, reduced from Raffaelle's "Madonna," by M. Constantin, 100*l.*

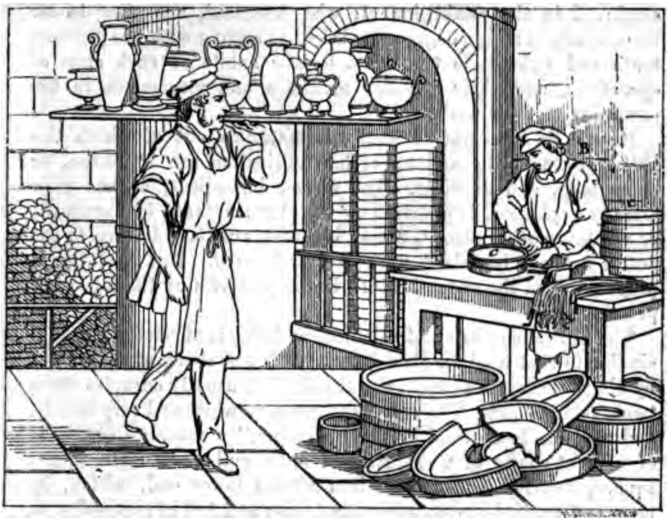


Fig. 43.—BAKING ROOM IN PORCELAIN WORKS.

THE POTTER'S ART.

CHAPTER V.

1. Process of throwing.—2. Turning.—3. Moulding.—4. Turning and Moulding combined.—5. Glazing.—6. Bisque firing.—7. Ovens.—8. Sèvres ovens.—9. Statistics of pottery.

1. The brief explanation of some of the processes by which the beautiful productions of this branch of industry are obtained, which have been given in the preceding pages, will be easily understood by all persons who may have had the pleasure and advantage of visiting any of the great porcelain-works. For the benefit of those who have not been so fortunate, we shall here give some more developed explanations of the succession of processes by which the raw clay is converted into the finished article; in doing which we shall avail ourselves of some admirably executed sketches, showing the interior of some of the principal workshops of a porcelain factory, which were prepared under the direction of the late M. Brongniart, director of the Royal porcelain works of Sèvres, and executed by Mr. Charles Develey, an artist

employed in the establishment, who possessed, according to M. Brongniart, in a high degree, the talent of seizing with the greatest truth and exactitude the characteristic habits of each class of operatives, and their peculiar attitudes and movements in the execution of their work.

It will be remembered that the materials out of which the potter produces the articles of his fabrication are 1° kaolin, or china clay, and 2° flints. The former ingredient, as has been already explained, is prepared by the clay merchant in Cornwall, or whatever other place the clay is found, and is delivered to the potter ready to be mixed with the flint earth. But the latter is prepared from the natural flints in the potteries by the following process:—

The flint stones are first calcined, and this is effected in a kiln similar to that used for lime-burning. These stones are separated by alternate layers of coal, and the burning usually occupies about twenty-four hours. The flints are then very white and very brittle, and ready to be crushed by the "stamper," a machine composed of upright shafts of wood, six feet long, and about eight inches square, heavily loaded with iron at the lower end, which, by means of applied power, are made to rise and fall in succession on the flints, contained in a strong grated box. It is then removed to the grinding vats, which are from twelve to fourteen feet in diameter, and four feet deep, paved with chert stone, large blocks of which, being also worked round by arms connected with a central vertical shaft, propelled by an engine, become a powerful grinding medium. This peculiar stone is used because of its chemical affinity to the flint, which, therefore, suffers no deterioration from the mixture of the abraded particles, which necessarily results from the friction, a matter of serious moment. In these vats the flint is ground in water until it attains the consistency of thick cream, when it is drawn off and conveyed by troughs into the washing chamber. Here it undergoes a further purification; more water is added, and it is kept in a state of gentle agitation, by means of revolving arms of wood, thus keeping the finer particles in suspension while the liquid is again drawn away in pipes to a tank below. The sediment is afterwards re-ground. The cleansing process is not yet complete, for when the fluid has passed into these tanks, to about half their depth, they are filled up with water, which is repeatedly changed, until it is considered sufficiently fine, and free from all foreign matters: it is then fit for use.

The next process consists in mixing the clay with the flint. This is accomplished by mixing both with water, so as to give them a creamy consistency, and to convert them into what the potters technically call *slip*. For this purpose the two slips, that of clay and that of flint, are successively run off into the blending reservoir, against the inner side of which are "gauging rods," by which the necessary proportion of each material is regulated. The mixture is now passed into other reservoirs, through fine sieves on "lawns," woven of silk, and containing 300 threads to the square inch. A pint of slip of Dorsetshire or Devonshire clay weighs 24 ounces, of proper consistence; of Cornish clay 26 ounces; and of flint 32 ounces. Finally, the slip is conveyed to a series of large open kilns, heated underneath by means of flues, and about 9 inches deep. The excessive moisture is thus evaporated, and in about twenty-four hours the mixture becomes tolerably firm in substance. It is then cut into large blocks and conveyed to an adjoining building to undergo the process of "milling." The mill is in the form of a hollow cone, inverted, with a square aperture or tube at the lower part. In the centre is a vertical shaft, set with broad knives. When this shaft is in action (worked by steam power), the soft clay is thrown in, and forced downwards, being alternately cut and pressed until it exudes from the aperture at the bottom, in a perfectly plastic state, and ready for the hand of the potter.*

The paste thus prepared would serve for the purposes of manufacture, but it is found that it may be considerably improved by leaving it for an interval, more or less protracted, several years for example, stored in damp vaults or cellars. It suffers a sort of *rotting*, becomes black, and evolves an offensive odour of the gas called sulphuretted hydrogen. These effects are easily explained. The paste, as prepared, always contains a proportion, however minute, of organic matter, which the previous preparation has failed to extricate from it. This matter by the influence of the humid air, undergoes a spontaneous combustion, and acting upon some traces of sulphates, which also remain as unextricated impurities in the paste, transforms them into sulphurets, and accordingly sulphuretted hydrogen is evolved.

The utility of all these processes, by which the minutest particles of organic matter are disengaged from the dough, will be understood when it is considered that even the presence of a single hair in the dough would be sufficient to spoil completely an article of porcelain of great beauty and value; for the organic matter thus buried in the material being decomposed by the action of the ovens, a gas would be developed which would produce air-bubbles or even cracks in the article.

To work the paste, when ready for the manufacture, it is once

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Catalogue of the Great Exhibition, p. 718.

more tempered by the potter, who for that purpose divides it into balls of convenient size , which he *slaps* with great force upon his table. The last air-bubbles are expelled from the dough by this process.

The formation of the dough into the fabricated article is effected, either by the processes of *throwing* and *turning* on the wheel, or by moulding, the latter being effected either by *pressure* or by *casting*.

The process of forming the article on the potter's wheel has been briefly explained in a former chapter. It will be more clearly comprehended by the aid of M. Develey's sketch of the thrower and turner's shop, represented in fig. 28 at the head of Chapter III.

A ball of dough is given to the thrower, A, of sufficient magnitude for the piece intended to be made. He places it on the centre of the circular plaster disc, which is attached to the top of his wheel, and which revolves with the wheel. By the dexterous application of his hands and fingers, the ball of dough passing through a succession of forms assumes ultimately that which is desired.

Some idea may be formed of this most ancient and characteristic operation of the potter's art by the aid of the diagrams, fig. 29 to fig. 34.

Let it be supposed that the shape of the vase to be formed is that represented in fig. 29. It will then be produced in two separate pieces, D and E, which after being formed on the wheel must be united and attached one to another by that general cement of the potter called SLIP.

Fig. 29.

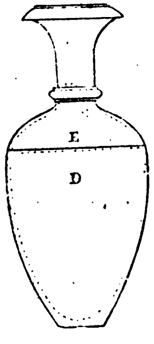


Fig. 30.

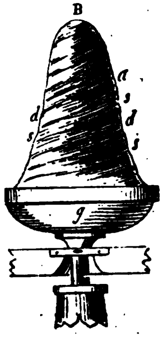
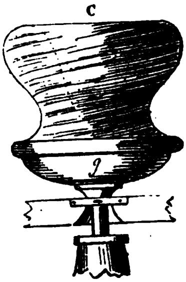


Fig. 31.



A ball of dough, B, fig. 30, sufficient to produce the lower part D, fig. 29, being placed on the wheel and put in rotation, is shaped by the hands and fingers of the thrower, assuming successively the forms, C, fig. 31, and D, fig. 32, the shape of the hollow part or interior being indicated by the dotted line. The traces of the fingers appear in the spiral lines, *d s*. The circular disc forming the top of the wheel is represented at *g*.

The ball of dough, A, fig. 33, after similar manipulation, takes the form, E, fig. 34. The parts D and E being united, the superfluous part of the dough is turned off so as to give the desired form to the external surface.

Fig. 32.

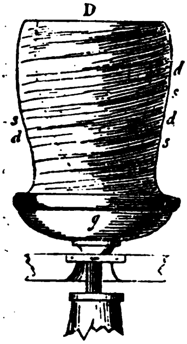


Fig. 33.

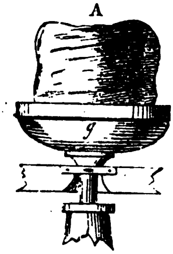
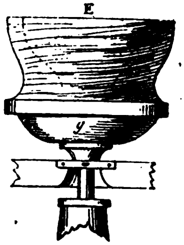


Fig. 34.



The peculiar attitude of the arms of the thrower, which is well represented in fig. 28, will be observed to bear a close resemblance to that represented in the ancient Egyptian drawing, fig. 5.

2. When the *thrown ware*, as it is called, which is thus produced, has been rendered sufficiently consistent by spontaneous air drying, it is transferred to the hands of the turner, who is represented at B, fig. 28, and who works at a wheel similar to the ordinary potter's wheel. This operative, by means of a cutting tool, renders the form of the article more exact and true, and shaves off all roughness and inequalities by a process precisely similar to that of turning with the ordinary lathe, only that in the present case the axis of the lathe is vertical, and the circular motion imparted to the article horizontal. The shavings which are detached in this process are mixed with fresh paste, to which they impart peculiar qualities.

Various tools and accessories appear in the figure, such as the gauge compasses, calipers, *c*, by which the diameter of the vase at different points is measured, the working drawing, *d*, which gives him both the profile and the dimensions, the latter being from time to time verified with the calipers.

3. The moulder's shop is represented in fig. 35, at the head of Chap. IV.

The work of the moulder consists of two processes; *first*, to impart the desired form to the piece; and *secondly*, to adapt and attach to the principal piece its various accessories, which are separately moulded or cast, such as handles, spouts, ears, &c.

The operative, A, places on a marble slab before which he stands a mass of dough which he flattens with a rolling-pin. Each end of the pin rests upon a lath by which it is prevented from pressing the dough below a certain thickness, and which also gives it a perfectly even motion, so that the cake of dough is not only of uniform thickness, but has also a perfectly even and uniform surface. This uniformity of surface on the under side it receives by pressure on the slab, and on the upper side by the regulated action of the roller.

Under the cake of dough, and between it and the slab, is previously spread a cloth, *b*, upon which it rests. By means of this cloth the operative is enabled to raise the dough from the slab without deranging its form.

The operative, B, having received it from A, thus supported by the cloth *b*, places it upon the mould, which, as here represented, will produce the inner or concave surface of a vase or cup, having a sort of fluted form. When the mould is completely covered with the dough, the operative, C, presses the dough strongly upon it with a sponge, so as to force it into exact contact with the most minute cavities of the mould. To accomplish this the more easily, the mould is placed upon the circular slab, *p*, supported on a vertical pillar, *f*, with which it turns freely, so that every side of the article to be moulded is brought successively under the hand of the operative.

Plates, dishes, and saucers, and in general the class of articles denominated "flat ware," are made from moulds, by which the inside or concave surface of the article is formed. The form is imparted to the convex surface by means of profiles usually made of fired clay and glazed. After the proper convex form is given by the turner C by means of the profile, the mould, with the article still upon it, is taken to the hot-air chamber, where it remains till it is tolerably dry. It is then brought back to the turner C, and the profile is again passed over it, by which the inaccuracies of form consequent upon shrinkage are corrected.

The operative, G, has just moulded or cast a handle from which he is removing the superfluous and excrescent parts with a tool, and cleaning out its cavities. He is about to attach it to the vase, as he has already done with the other handle. This he accomplishes by moistening, with the creamy liquid called *slip*, the surfaces to be united. This slip acts as a cement, becoming almost immediately hard enough to retain the handle in its place.

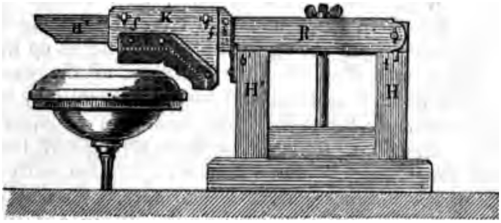
A number of handles ready moulded or cast are lying on the slab beside G, ready to be attached to similar articles. Various plaster moulds appear on the floor near the table.

The convex surface of the article to be moulded is produced in like manner, by pressing a concave mould upon it. Some of these concave moulds appear on the floor.

The process of moulding by casting has been explained in the case of statuary porcelain.

4. The operations of the thrower and moulder are sometimes abridged by combining them. The apparatus represented in fig. 36 supplies an example of this.

Fig. 36.



It consists of a porte-calibre, K, and a copper bar, RR', which plays on a hinge or pivot, at one extremity, and is supported on a frame, HH', of wood solidly attached to the table of the wheel. It is raised and lowered by turning it on the hinge, *t*, and when lowered is supported on the upright H' at *t'*. The porte-calibre slides on this, its motion being regulated by a groove. To this is attached by screws the "calibre," or profile, *c*, which is formed to correspond with the shape and mouldings of the article to be produced.

The mould which gives the form to one side of the article, (suppose for example the concave or upper surface of a plate,) being attached to the disc of the potter's wheel, a cake of dough of the proper magnitude and thickness is laid over it, and pressed upon it by a wet sponge, so as to cause it to apply itself closely at every part to the surface of the mould. When this is accomplished the calibre or profile is lowered gradually upon it, and the wheel being put in revolution, the convex side or bottom of the plate receives its form in the same manner as an object placed in the chuck of a turner's lathe is shaped by a cutting tool guided by a slide-rest.

By this process the article receives a perfectly uniform thickness and diameter, the edges being subsequently rounded on the wheel in the usual way.

5. Ware which has received its proper forms by the processes above described and which has been to a certain degree hardened by air drying or exposure to a high artificial temperature, is in what is called by potters the *green* state. It is completely dry, all moisture being perfectly expelled from it, but is still very porous, so that it would readily imbibe water or other liquid which might be poured into it, or in which it might be immersed. It is in this state that the process of glazing, already described, must be executed.

The materials comprised in the various glazes commonly used for china and earthenware are—Cornish stone, flint, white lead, glass, whiting, &c. These, having been ground together in proper proportions to the consistence of milk, form the glaze. The process is effected in large buildings termed "dipping-houses" (china and earthenware being kept separate), fitted up with tubs for the glaze, and stages for the reception of the ware when dipped, upon which it is dried and heated, generally by means of a large iron stove or "cockle," from which iron pipes, extending in various directions, convey the heat throughout the whole extent of the "houses." Each dipper is provided with a tub of glaze, in which he immerses the bisque ware. We may note the results of practice and experience in imparting a facility and dexterity of handling, so necessary to perfection in this process. The ware is held so that as small a portion as possible shall be covered by the fingers; it is then plunged in the glaze, which, by a dexterous jerk, is made not only to cover the entire piece, but, at the same time, so disperses it, that an equal and level portion is disposed over the whole surface, which, being porous, imbibes and retains it. The ware is handed to the dipper by a boy, and another removes it when dipped to the drying or "hot-house." The glaze is opaque till fired, so that the design of pattern executed on the bisque is completely hid, after dipping, till they have been submitted to the glost fire. An able workman will dip about seven hundred dozen plates in a day.*

The dipping house is represented in fig. 37. The dippers, A, and B, immerse unglazed plates in the vessel containing the glaze, which, as already explained, is a creamy liquid in which the vitrifiable matter is mixed, and held in suspension, just as mud is in water. When the plate is withdrawn from the glaze it is held over it so as to allow all the liquid not absorbed by the plate to drip off, as represented in the case of the dipper B.

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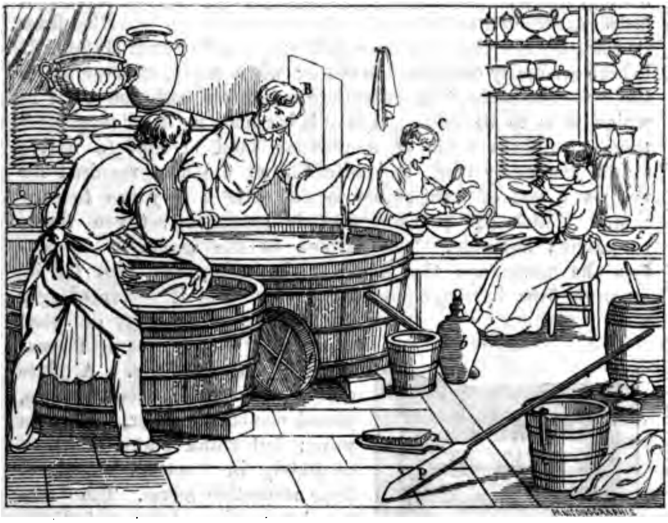
* Catalogue of the Great Exhibition, 725.

The females C and D are employed in detaching from articles which have been dipped the parts of the glaze which are redundant. Thus C scrapes off, with a bladed tool, a portion of the glaze where it is too thick, or where it remains attached to the surface in round drops called *tears*. The other, D, removes with a brush or a piece of felt the glaze from the circular ring at the bottom of a plate, that being the part on which it stands when placed in the oven. If this precaution were not taken, the plate would adhere to the oven by means of the portion of glaze on this circular edge when vitrified.

Fig. 37.



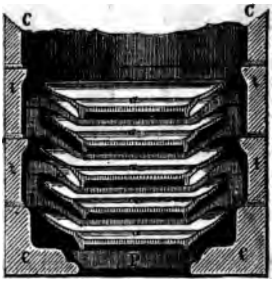
When the articles are thus prepared, they are put into an oven where they are exposed to a temperature which vitrifies the glaze upon their surface.

It is necessary that the glaze thus applied to the article should be such as will vitrify at a temperature lower than that which would soften the paste of which the article is made, and thus deform the article itself.

In the figure are seen several tools and utensils used in the process of glazing. Thus *g* is the wooden grating upon which the article is left to drip after being withdrawn from the glaze; *t* is a sieve which is used to strain off any solid impurities which may be seen floating in the glaze; *p* is the spatula used from time to time to agitate the glaze so as to prevent the pulverulent matter suspended in it from subsiding, and to maintain it of an uniform consistency. A bottle, *b*, contains vinegar, which is mixed in a certain proportion with the glaze; a small cup, *c*, containing liquid glaze is placed near the female D, who dipping a brush in it retouches all parts of the article on which the glaze is too thin or altogether wanting.

6. When the wares have been prepared for the final process of baking, which is called technically *bisque firing*, they are carried on boards as represented in fig. 43, to the "green-house," so called from its being the receptacle for ware in the "green" or unfired state. It is here gradually dried for the ovens: when ready, it is carried to the "sagger-house," in immediate connexion with the oven in which it is to be fired, and here it is placed in the "saggers:" these are boxes made of a peculiar kind of clay (a native marl), previously fired, and infusible at the heat required for the ware, and of form suited to the articles they are to contain. A little dry pounded flint is scattered between them, to prevent adhesion. The purpose of the sagger is to protect the ware from the flames and smoke, and also for its security from breakage, as in the clay state it is exceedingly brittle, and when dry, or what is called "white," requires great care in the handling. A plate sagger will hold twenty plates, placed one on the other, of earthen ware; but china plates are fired separately in "setters" made of their respective forms. The "setters" for china plates and dishes answer the same purpose as the "saggers," and are made of the same clay. They take in one dish or plate each, and are "reared" in the oven in "bungs" one on the other.

Fig. 38.



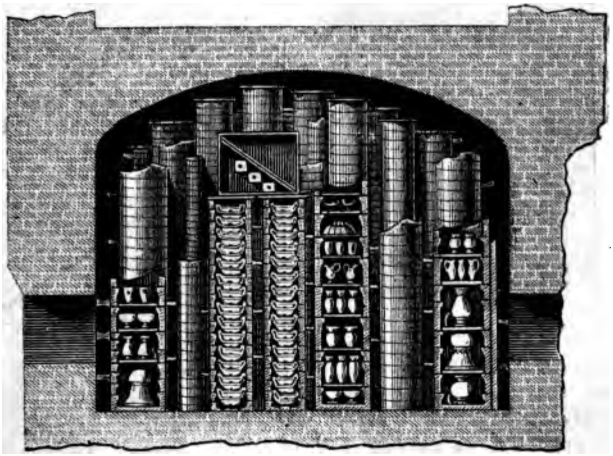
In fig. 38 is represented a pile of saggers containing plates. It will be perceived that in this case each sagger consists of two parts, one, *t t*, cylindrical, and the other, *i i*, having a form corresponding to that of the plate, the rim, at the bottom of which rests upon it. These saggers are placed one over the other, so as to form a vertical pile.

It will be evident, from what has been here explained, that the magnitude, form, and internal structure of the saggers must vary with those of the articles which they are intended to contain.

The disposition and arrangement of the piles of saggers in the oven are represented in fig. 39, some of the piles being represented in section, to show the arrangement of the articles within the saggers.

The process of baking highly decorated ornamental articles in porcelain is a process requiring much greater precaution, and a different sort of apparatus. It is usually effected by means of special furnaces and saggers, of which an example is presented in fig. 40. The furnace is constructed in fire-clay or cast-iron, and the fire is regulated in it with the greatest care. Trial pieces are from time to time taken from the opening, *v*, by which the effect of the firing on the several colours is ascertained.

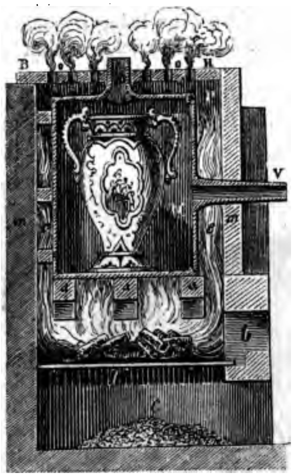
Fig. 39.



7. The hovels in which the ovens are built form a very peculiar and striking feature of the pottery towns, and forcibly arrest the attention and excite the surprise of the stranger, resembling as they closely do a succession of gigantic bee-hives. They are constructed of bricks, about 40 feet diameter, and 35 feet high, with an aperture at the top for the escape of the smoke. The "ovens" are of a similar form, about 22 feet diameter, and from 18 to 21 feet high, heated by fire-places, or "mouths," about nine in number, built externally around them. Flues in connection with these converge under the bottom of the oven to a central opening,

drawing the flames to this point, where they enter the oven: other flues, termed "bags," pass up the internal sides to the height of about four feet, thus conveying the flames to the upper part.

Fig 40.



When "setting in" the oven, the firemen enter by an opening in the side, carrying the saggers with the ware placed as described: these are piled one upon another from bottom to top of the oven, care being taken to arrange them so that they may receive the heat (which varies in different parts) most suited to the articles they contain. This being continued till the oven is filled, the aperture is then bricked up: the firing of earthenware bisque continues sixty hours, and of china forty-eight.

The quantity of coals necessary for a "bisque" oven is from 16 to 20 tons; for a "glost" oven from 4½ to 6 tons.

The ware is allowed to cool for two days, when it is drawn in the state technically termed "biscuit," or bisque, and is then ready for "glazing," except when required for printing, or a common style of painting, both of which processes are done on the "bisque" prior to being "glazed."

8. A porcelain oven of three stages, used in the Sèvres manufactory, is represented in fig. 41 and fig. 42, the former being the exterior view, and the latter a vertical section by a plane through its centre. Each of the lower stages, L and L′, is heated by four furnaces, from which the flame and heated air is drawn into the oven through the flues *g*. Fire-doors of plate-iron are provided, by which the mouths of the furnaces and ashpits can be closed or opened at pleasure.

When the several stages of the ovens are charged with the wares to be baked, the firing is conducted so as to raise the temperature by slow and regulated gradation. The fires, at first moderate in their force, are constantly augmented for from sixteen to twenty hours. When the oven is thus well heated, the great firing is commenced by giving full charges of fuel to all the furnaces. The oven itself, which is cylindrical below, terminating in a conical roof with an opening at top, governed by a regulating plate or damper, *t*, discharges the functions of a chimney, so that the currents of flame and heated air drawn from the furnaces severally entering the oven, circulate around the ware with

Fig. 41.

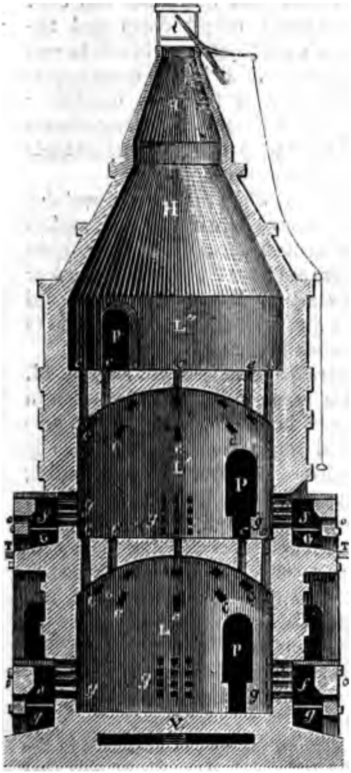
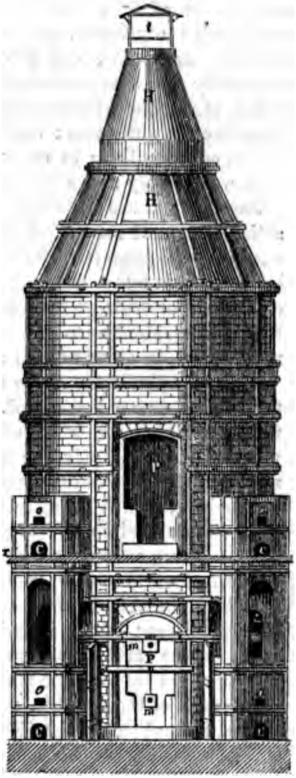


Fig. 42.



which it is charged, and rising to the conical roof, H H, escape at the opening *t*. The current passes from stage to stage through orifices, *c*, *c*, *c*, formed in the flooring for that purpose.

The great firing which completes the process of baking is maintained for ten or twelve hours.

The oven is built with fire-bricks, bound by bracings of iron, as represented in fig. 41. In each stage there is provided a door, P, through which the charge and discharge is made, and which during the process of baking is walled up with brickwork. In this brickwork small holes, *m m*, are left, through which the oven-man from time to time takes out trial-pieces, which are pieces of clay of known quality, and which indicate by the effect produced upon them the progress which the baking has made. When the appearance of these trial-pieces shows that the firing has been sufficiently continued, the furnace and ashpit doors and the damper *t* are closed, and the oven, with its charge, is left to cool gradually for twenty-four or thirty hours. It is not necessary to delay the withdrawing of the pieces from the oven until they have become quite cold; but the sudden alteration of temperature would occasion them to crack if they were taken out while their heat was greatly above that of the atmosphere.

Some potters are occasionally tempted, when the furnace contains articles of small value, to risk the damage here mentioned, and to withdraw the saggers with their contents without delay, their object being to profit by the heat of the furnace either for introducing a new charge, or for drying a fresh set of saggers. No one, however, would be so improvident as to expose the finer descriptions of porcelain to this hazard, in order to gain any such immaterial advantage.

From the similarity of its appearance to well-baked ship bread, the ware is now called *biscuit*. Its permeability to water when in this state fits it for being employed in cooling liquids. If previously soaked in water, the gradual evaporation from its surface by means of the air, causes an absorption of heat from the surrounding atmosphere, which is again supplied by neighbouring objects, until an equilibrium of temperature is restored.

9. As there are no excise or other regulations affecting the manufacture of earthenware, there are no official documents or records by which the actual extent of the manufacture can be ascertained with precision; but it is estimated that at the Potteries alone the value of the earthenware produced annually is about 1,700000*l.*, and that the value of the manufactures of Worcester, Derby, and other parts of the country, may amount to about 750000*l.*, making a total annual value of 2,450000*l.*

The value of the gold consumed annually at the Potteries in the ornamentation of porcelain is 36400*l.*, and, since about half that amount is consumed in the other seats of the manufacture, it may be stated that the total value of the gold used annually in England in this manufacture is about 54600*l.*

The quantity of coals consumed annually at the Potteries is 468000 tons, and, about half that amount being consumed in other factories, it may be stated at about 700000 tons—an amount equal to what is consumed in working all the railways of the United Kingdom.*

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* See Lardner's Railway Economy, p. 83.

POTTERY STATISTICS.

It appears from the official reports that, in 1841—the latest year in which official returns have been made public—the declared value of the earthenware exported was 600759*l.*; in 1837 the declared value was 563238*l.*. In the four years ending 1841, an increase, therefore, took place in this export trade of 37521*l.* upon 563238*l.* If this same rate of increase only has been maintained since 1841, the present annual export trade must have a declared value of a million sterling.

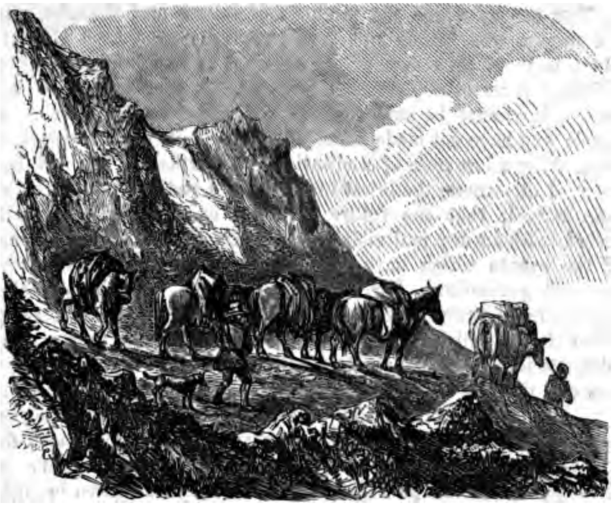
But, since the declared is known to be on an average one-fourth less than the true value, we may assume that the present total annual amount of the export trade in earthenware is about 1,300000*l.*

The proportion in which this enormous export is distributed among the different countries of the world is exhibited in the following table. In the second column is given the proportion of every 100*l.* value exported received by each of the countries named in the first column, and in the third column is given the number of pieces of ware out of 10000 received by each country respectively:—

Countries.	Per Cent. of the total Value.	Per 10000 of Number of Pieces.
United States	37·58	3560
North American British colonies . . .	6·95	778
Brazil	6·36	1010
British East Indies	5·00	310
British West Indies	4·42	387
German States	4·28	401
Holland	4·11	397
Foreign West Indies	3·50	396
Australian colonies	2·69	216
Denmark	2·31	257
Italy and Italian islands	2·25	145
Sumatra, Java, and Indian islands . . .	1·39	168
Spain and the Balearic islands	1·08	145
Western Africa	0·85	73
Cape of Good Hope	0·79	64
Channel Islands	0·69	65
Turkey	0·67	55
Russia	0·65	40
All other countries	14·43	1533
Total	100·00	10000

It appears from this table that the United States is our great foreign customer for this manufacture, taking in value 37½ per cent., and in quantity 35½ per cent., of our entire export. Of the remainder, our North American colonies, Brazil, and India, take 18 per cent.

In 1841, our export in this manufacture formed about 30 per cent. of its estimated total value. We have no returns later, but it is probable that at present the export forms a much larger proportion of the entire value fabricated.



LOCOMOTION AND TRANSPORT,

THEIR INFLUENCE AND PROGRESS.

CHAPTER I.

INFLUENCE OF IMPROVED TRANSPORT ON CIVILISATION.

1. Art of transport essential to social advancement. — 2. Its rapid advancement in modern times.—3. Commerce mainly dependent on it. —4. Its conditions.—5. Its advantages, its influence on price.—6. Example of cotton. — 7. Agricultural products. — 8. Reciprocal advantages to rural and urban population.—9. Absence of good means of transport injurious to France.—10. Renders worthless or injurious articles serviceable and valuable.—11. Stimulates both production and consumption.—12. Increases the demand for labour. 13. Effects of railways.—14. Advantages of increased speed.—15. In the transport of cattle.—16. Steam vessels not so well adapted to this.—17. Supply of milk to towns.—18. Advantages to farmers and landlords.—19. Advantages of steam navigation.—20. Advantages of personal locomotion.—21. In the case of the working population. —22. Influence on the value of land.—23. Advantages to the population of large cities.—24. Relative speed of horse coaches and railways. 25. Military advantages.—26. Offers inducements to peace and the means of abridging war.—27. Influence on the diffusion of knowledge. —28. The electric telegraph.—29. Journalism.

LOCOMOTION AND TRANSPORT.

1. THE art by which the products of labour and thought, and the persons who labour and think, are transferred from place to place, is, more than any other, essential to social advancement. Without it no other art can progress. A people who do not possess it cannot be said to have emerged from barbarism. A people who have not made some advances in it, cannot yet have risen above a low state of civilisation. Nevertheless, this art has been, of all others, the latest in attaining a state of perfection, so late, indeed, that the future historian of social progress will record, without any real violation of truth, that its creation is one of the events which have most eminently signalised the present age and generation. For, although transport by land and water was practised by our forefathers, its condition was so immeasurably below that to which it has been carried in our times, that a more adequate idea of its actual state will be conveyed by calling it a new art, than by describing it as an improvement on the old one.

2. But if human invention has been late in directing its powers to this object, it must be admitted to have nobly compensated for the tardiness of its action by the incomparable rapidity of advancement it has produced, when once they have been brought into play. Within a hundred years, more has been accomplished in facilitating and expediting intercommunication, than was effected from the creation of the world to the middle of the last century. This statement may, perhaps, appear strained and exaggerated, but it will bear the test of examination.

3. The geographical conditions of the world, the distribution of the people who inhabit it, and the exclusive appropriation of its natural productions destined for their use to the various countries of which it consists, have imposed on mankind the necessity of intercommunication and commerce. Commerce is nothing more than the interchange of the productions of industry between people and people. Such interchange presupposes the existence of the art of transport by land and water. In proportion to the perfection of this art will be the extent of commerce.

A people incapable of communicating with others must subsist exclusively upon the productions of its own labour and its own soil. But nature has given us desires after the productions of other soils and other climates. Besides this, the productions of each particular soil or country are obtainable in superfluity. They are infinitely more in quantity than the people by whom and amidst whom they are produced have need of; while other and distant peoples are in a like situation, having a superfluity of some products and an insufficiency or a total absence of others. The people of South Carolina and Georgia have a superfluity of cotton, the people of the West India Islands have a superfluity of coffee and tobacco, the people of Louisiana have a superfluity of sugar, the people who inhabit the vast valley of the Upper Mississippi and Missouri have a superfluity of corn and cattle, the people of civilised Europe have a superfluity of the products of mechanical labour, those of France have a superfluity of silk goods, those of England of manufactured cotton, pottery, and hardware. Each of these various peoples is able and willing to supply the others with those productions in which themselves abound, and to receive in exchange those of which they stand in need, and which abound elsewhere.

4. But, to accomplish such interchanges, means of transport must be provided, and this transport must be sufficiently cheap, speedy, safe, and regular, to enable these several productions to reach their consumers, and be delivered on such terms and conditions as will be compatible with the ability to purchase them.

5. Among the advantages which attend improved means of transport, one of the most prominent is that of lowering the price of all commodities whatever in the market of consumption, and thereby stimulating production. The price paid for an article by its consumer consists of two elements: 1st, the price paid for the article to its producer at the place of its production; and, 2ndly, the expense of conveying it from that place to the consumer. In this latter element is included the cost of its transport and the commercial expenses connected with such transport. These last include a variety of items which enter largely into the price of the commodity, such as the cost of transport, properly so called, the interest on the price paid to the producer proportionate to the time which elapses before it reaches the consumer, the insurance against damage or loss during the transport. This insurance must be paid directly or indirectly by the consumer. If it be not effected by those who convey the commodity to the consumer, the value of the goods which may be lost or damaged in the transport will necessarily be charged in the price of those which arrive safe. In either case the consumer pays the insurance. There are also the charges for storage, packing, transhipment, and a variety of other commercial details, the total of which forms a large proportion of the ultimate price.

In many cases, these expenses incidental to transport amount to considerably more than half the real price of the article; in some they amount to three-fourths or four-fifths, or even a larger proportion.

6. Let us take the example of raw cotton produced on the plains of South Carolina or Georgia. This article is packed in bales at the place of production. These are then transported to Charleston or Savannah, whence they are exported to Liverpool. Arriving

at Liverpool, they are transferred upon the railway, by which they are transported to Manchester, Stockport, Preston, or some other seat of manufacture. The raw material is there taken by the manufacturer, spun into thread, woven into cloth, bleached and printed, glazed, and finished. It is then repacked, and again placed on the railway and transported once more to Liverpool, when it is re-embarked for Charleston or Savannah, for example. Arriving there, it is again placed on a railway or in a steam-boat, and is transported to the interior of the country, and finally returns to the very place at which it originally grew, and is repurchased by its own producer. Without going into arithmetical details, it will be abundantly apparent how large a proportion of the price thus paid for the manufactured article is to be placed to the account of the transport and commercial expenses. The article has made the circuit of almost half the globe before it has found its way back in its manufactured state.

7. The products of agricultural labour have, in general, great bulk with proportionately small value. The cost of transport has consequently a great influence upon the price of these in the market of consumption. Unless, therefore, this transport can be effected with considerable economy, these products must be consumed on the spot where they are produced.

In the case of many animal and vegetable productions of agriculture, speed of transport is as essential as cheapness, for they will deteriorate and be destroyed by the operation of time alone. Without great perfection, therefore, in the art of transport, objects of this class must necessarily be consumed in the immediate neighbourhood of the place where they are raised. Such are, for example, the products of the dairy, the farm-yard, and the garden.

8. In countries where transport is dear and slow, there consequently arises great disadvantage, not only to the rural, but also to the urban population. While the class of articles just referred to are at a ruinously low price in the rural districts, they are at a ruinously high price in the cities and larger class of towns. In the country, where they exist in superfluity, they fetch comparatively nothing : in the towns, where the supply is immeasurably below the demand, they can only be enjoyed by the affluent.

But if sufficiently cheap and rapid means of transport be provided, these productions find their way easily to the great centres of population in the towns, and the rural population which produces them receives in exchange innumerable articles of use and luxury of which they were before deprived.

9. France, one of the most civilised states of Europe, exhibits a deplorable illustration of this. Notwithstanding the fertility of

her soil, the number, the industry, and intelligence of her population, the products of every description, animal and vegetable, which abound in her territory, yet, from the absence of sufficiently easy means of intercommunication, these advantages have been hitherto almost annihilated. All these productions, in the place where they are raised, can be obtained at a lower price than in most other countries; and yet, in consequence of the cost of transport, they would attain, if brought to the place where they are in demand, a price which would amount to a prohibition on their consumption. From this cause the industry of France has long been to a great extent paralysed.

10. In some cases the price of an article at the place of consumption consists exclusively of the cost of transport. An article has frequently no value in the place where it is found, which nevertheless would have a considerable value transported elsewhere. Numerous instances of this will occur in the case of manures used in agriculture. Every reduction, therefore, which can be made in the cost of the transport of these, will tend in a still greater proportion to lower their price to those who use them.

Cases even occur in which the cost of transport is actually greater than the price paid for an article by the consumer. This, which would seem a paradox, is nevertheless easily explained. An article in a given place may be a nuisance, and its possessor may be willing to pay something for its removal. This article, however, transported to another place, may become eminently useful, and even be the means of stimulating profitable production. The cleansing the common sewers of a city affords a striking example of this. The filth and offal which are removed are a nuisance where they exist, and may even be the cause of pestilence and death. Transported, however, to the fields of the agriculturist, they become the instruments of increased fertility. Cases may be cited where the whole cost of transport will be more than covered by the sum paid for the removal of the nuisance.*

11. Every improvement in the art of transport having a tendency to diminish cost, and augment speed and safety, operates in a variety of ways to stimulate consumption and production, and thereby advance national wealth and prosperity. When the price of an article in the market of consumption is reduced by this cause, the demand for it is increased: 1st, by enabling former consumers to use it more freely and largely; and, 2ndly, by placing it within the reach of other classes of consumers who were before compelled to abstain from it by its dearness. The increase of

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* In Aberdeen the streets were swept every day, at an annual cost of 1400*l.*, and the refuse brought in 2000*l.* a-year. In Perth the scavenging cost 1300*l.* per annum, and the manure sold for 1730*l.*

consumption from this cause is generally in a larger ratio than the diminution of price. The number of consumers able and willing to pay one shilling for any proposed article is much more than twice the number who are able and willing to pay two shillings for the same article.

But consumption is also augmented in another way by this diminution of price. The saving effected by consumers who, before the reduction, purchased at the higher price, will now be appropriated to the purchase of other articles of use or enjoyment, and thus other branches of industry are stimulated.

12. The improvements which cheapen transport, necessarily including the expenditure of less labour in effecting it, might seem, at first view, to be attended with injury to the industry employed in the business of transport itself, by throwing out of occupation that portion of labour rendered superfluous by the improvement. But experience shows the result to be the reverse. The diminished cost of transport invariably augments the amount of commerce transacted, and in a much larger ratio than the reduction of cost; so that, in fact, although a less amount of labour is employed in the transport of a given amount of commodities than before, a much larger quantity of labour is necessary by reason of the vast increase of commodities transmitted. The history of the arts supplies innumerable examples of this. When railways were first brought into operation, it was declared, by the opponents of this great improvement (for it had opponents, and violent ones), that not only would an immense amount of human industry connected with the business of land carriage be utterly thrown out of employment, but also that a great quantity of horses would be rendered useless. Experience was not long in supplying a striking proof of the fallacy of this prevision.

13. The moment the first great line of railway was brought into operation between Liverpool and Manchester, the traffic between those places was quadrupled; and it is now well known that the quantity of labour, both human and chevaline, employed in land carriage where railways have been established, has been increased in a vast proportion, instead of being diminished.

In 1846 there were seventy-three stage-coaches or lines of omnibus employed in the transport of passengers to and from the several stations of the North of France Railway, which supplied 176 arrivals and departures, had 5776 places for passengers, and employed daily 979 horses. In the six months ending 31st December, 1846, these coaches transported 486948 passengers.

Improvements in transport which augment the speed, without injuriously increasing the expense or diminishing the safety, are attended with effects similar to those which follow from cheapness.

14. A part of the cost of transport consists of the interest on the cost of production chargeable for the time elapsed between the departure of the article from the producer and its delivery to the consumer. This element of price is clearly diminished in the exact proportion to the increased speed of transport.

But increased speed of transport also operates beneficially on commerce in another way. Numerous classes of articles of production become deteriorated by time, and many are absolutely destroyed, if not consumed within a certain time. It is evident that such articles admit of transport only when they can reach the consumer in a sufficiently sound state for use; various classes of articles of food come under this condition.

While the Houses of Parliament were occupied with the numerous railway acts which have been brought before them, a great mass of evidence was produced illustrating the advantages which both producer and consumer would obtain by the increased cheapness and expedition of transport which railways would supply. It was shown that the difficulties attending transport by common roads affected, in an injurious manner, the grazier who supplied the markets with veal and lamb. Lambs and calves were generally sent by the road; and when too young to leave the mothers for so long a time as the journey required, the producer was obliged to send the ewes or cows with them for at least a part of the way. This also rendered it impossible to send them to market sufficiently young, which it would have been advantageous to do, that the mothers might feed off earlier.

15. But, independently of this, the animals of every species driven to market on the common roads were proved to suffer so much from the fatigue of the journey, that when they arrived at market their flesh was not in a wholesome state. They were often driven till their feet were sore. Sheep frequently had their feet literally worn off, and were obliged to be sold on the road for what they would fetch. Extensive graziers declared that, in such cases, they would be gainers by a safe and expeditious transport for the animals, "even though it cost double the price paid to the drovers."

Butchers engaged in large business in London proved that the cattle driven to that market from considerable distances sustained so much injury that their value was considerably lessened, owing to the inferior quality of the meat, arising from the animal being slaughtered in a diseased state; that the animal being fatigued and overdriven "became feverish, his looks became not so good, and he lost weight by the length of the journey and the fatigue."

16. It was shown further, that even steam-vessels, when they could be resorted to, did not altogether remove this objection. Cattle arriving from Scotland in steam-vessels are found in London to be

in an unnatural state; "they seem stupified, and in a state suffering from fatigue."

It is not merely the fatigue of travelling which injures the animal, but also the absence from its accustomed pasture. The injury from this cause is more or less, under different circumstances, but always considerable: in order to obviate this, a large portion of the meat supplied to the London market was slaughtered in the country, and came in this state, in winter, from distances round London to the extent of one hundred miles. In warm weather a large quantity of it was spoiled. The transport of calves and lambs from a distance greater than thirty miles is altogether impracticable by common roads, and even from that distance is attended with difficulty and injury.

To convey these and other live cattle from a great distance, not only speed but evenness of motion is indispensable. Now these two requisites cannot be combined by any other means than the application of steam-engines upon a railroad.

The whole of the evidence showed that the supply of animal food to the metropolis was not only defective in quantity, but of unwholesome quality—comparatively, at least, with what it might be, if the tract from which it could be supplied were rendered more extensive.

17. But, forcibly as the evidence bore on this species of agricultural produce, it was still stronger respecting the produce of the dairy and the garden. Milk, cream, and fresh butter, vegetables of every denomination, and certain descriptions of fruit, were usually supplied exclusively from a narrow annulus of soil which circumscribes the skirts of great cities. Every artificial expedient was resorted to, in order to extort from this limited portion of land the necessary supplies for the population. The milk was of a quality so artificial, that we know not whether, in strict propriety of language, the name milk can be at all applied to it. The animals that yielded it were fed, not upon wholesome and natural pasturage, but, in a great degree, on grain and similar articles. It will not be supposed that the milk thus yielded is identical in wholesome and nutritious qualities with the article which could be supplied if a tract of land, of sufficient extent for the pasturage of cattle, was made subservient to the wants of such cities. Add to this that, inferior as must be under such circumstances the quality of the milk, there exist the strongest temptations to the seller who retails it to adulterate it still further before it finds its way to the table of the consumer.

Since the introduction of transport by railways, we see attached to the fast trains, morning and afternoon, numerous waggons *loaded with* tier over tier of milk-cans for the supply of the metropolitan population. Milk is thus brought from pastures at great distances from the cities where it is consumed. In Paris the benefits of this have been very conspicuous.

18. The benefits to farmers and landlords, as well as to the inhabitants of towns, by carrying extensive lines of railroad through populous districts, connecting them with those places from which supplies of food and other necessaries might be obtained, are always considerable. The factitious value which tracts of land immediately surrounding the metropolis and large towns acquire from the proximity of the markets, is thus modified, and a portion of their advantages transferred to the more remote districts; thus equalising the value of agricultural property, and rendering it, in a great measure, independent of local circumstances. The profit of the farmer and the rent of the landlord are augmented by the reduced cost of transport, while the price paid by the consumer is diminished; the advantages of centralisation are realised without incurring the inconvenience of crowding together masses of people within small spaces, and the whole face of the country is brought to the condition, and made to share the opportunities of improvement which are afforded by a metropolis and by towns of the larger class.

19. Steam navigation affords many striking examples of like advantages obtained in the transport of perishable productions.

Pines are now sold in the markets of England which are brought from the West Indies; various sorts of fruits are likewise brought from the countries on the coast of Europe which could not be transported in sailing vessels, as they would not keep during the voyage. Oranges are sent in large quantities from the Havannah to New Orleans and Mobile, in the United States: when they are brought by sailing vessels, a large proportion of the cargo is lost by the destruction and deterioration of the fruit; when sent by steamers, they arrive sound.

The utility of an article often depends on its place. Thus, what is useless at one part of the world will become eminently valuable if transmitted to another. We have already given examples of this in the case of agricultural manures. Others present themselves. Ice at mid-winter in Boston, Halifax, or St. John's, has no value; but this ice, properly packed and embarked, is transmitted to the Havannah or Calcutta, where a price is readily obtained for it which pays with profit the cost of the voyage.

Like all the other effects of improved transport, this reacts and produces collateral benefits. The ships thus enabled to go to Calcutta laden with a cargo which costs nothing and produces a considerable profit, instead of going in ballast, which would be attended with a certain expense, return with cargoes which again become profitable in the port from which they sailed, and which they could not have brought with profit unless aided by the expedient just mentioned.

20. Important as are improvements in the transport of the products of industry, they are less so than those which facilitate the transport of persons. Here speed becomes of paramount importance. In the case of the products of industry, the time of the transport is represented only by the interest on the cost of production of the article transmitted.

In the case of the transport of persons, the time of transport is represented by the value of the labour of the travellers, and their expenses on the road; and as travellers in general belong to the superior and more intelligent classes their time is proportionally valuable.

21. When cheapness can be sufficiently combined with speed, considerable advantage is gained by the operative classes.

The demand for labour in the several great centres of population varies from time to time, sometimes exceeding, and sometimes falling short of the supply. In the latter case, the operative having little other capital save his bodily strength, is reduced to extreme distress, nay, often even to mendicancy.

In the former case, the producer is compelled to pay an excessive rate of wages, which falls disadvantageously on the articles produced, in the shape of an undue increase of price, and thereby checks consumption. But although the equilibrium between supply and demand in the labour market is liable to be thus deranged, it rarely or never happens that it is subject to the same derangement in all the centres of population. Supply is never in excess everywhere at once, nor is it in all places at once deficient. Improvements in transport, which will render travelling cheap, easy, and expeditious, so as to bring it within the means of the thrifty and industrious operative, will enable labour to shift its place and seek those markets in which the demand is greatest. Thus, the places where the supply is in excess will be relieved, and those where the demand is in excess will be supplied.

22. The extent of soil by which great cities are supplied with perishable articles of food, is necessarily limited by the speed of transport. A ring of country immediately about a great capital, is occupied by market gardens and other establishments for supplying the vast population collected in the city with their commodities. The width of this ring will be determined by the speed with which the articles in question can be transported. It cannot exceed such a breadth as will enable the products raised at its extreme limit to reach the centre in such a time as may be compatible with their fitness for use.

It is evident that any improvement in transport which will double its speed will double the radius of this circle; an improvement which will treble its speed will increase the same radius in a threefold proportion. Now, as the actual area or quantity of soil included within such a radius is augmented, not in the simple ratio of the radius itself, but in the proportion of its square, it follows that a double speed will give a fourfold area of supply, a triple speed a ninefold area of supply, and so on. How great the advantages therefore are, which in this case attend increased speed, are abundantly apparent.

23. So far as relates to the transport of persons, the advantages of increased speed are equally remarkable. The population of a great capital is condensed into a small compass, and, so to speak, heaped together, by the difficulty and inconvenience of passing over long distances. Hence has arisen the densely populated state of great cities like London and Paris. With easy, cheap, and rapid means of locomotion, this tendency, so adverse to physical enjoyment and injurious to health, is proportionally neutralised. Distances practically diminish in the exact ratio of the speed of personal locomotion. And here the same arithmetical proportion is applicable. If the speed by which persons can be transported from place to place be doubled, the same population can, without inconvenience, be spread over four times the area; if the speed be tripled, it may occupy nine times the area, and so on.

Every one who is acquainted with the present habits of the population of London, and with those which prevailed before the establishment of railways, will perceive the practical truth of this observation. It is not now unusual for persons whose place of business is in the centre of the capital, to reside with their families at a distance of from fifteen to twenty miles from that centre. Nevertheless, they are able to arrive at their respective shops, counting-houses, or offices, at an early hour of the morning, and to return without inconvenience to their residence at the usual time in the evening. Hence in all directions round the metropolis in which railways are extended, habitations are multiplied, and a considerable part of the former population of London has been diffused in these quarters. The same will, of course, be applicable to the country which surrounds all other great towns. It is felt at Paris, Brussels, Berlin, Dresden, Vienna, and other capitals of Europe, just in the same proportion in which they are supplied with railway communication.

This principle of diffusion, however, is not confined to the towns only. It extends to an entire country when well intersected by lines of easy, rapid, and cheap communication.

The population, instead of being condensed into masses, is more uniformly diffused; and the extent of the diffusion which may be thus effected, compatibly with the same degree of intercourse, will be, to use an arithmetical phrase, in the direct proportion of the square of the speed of locomotion.

24. The common average of the speed of diligences in France and other parts of the Continent is two leagues, or about five miles, an hour. The speed of stage-coaches in England, before the establishment of railways, did not average eight miles an hour. According to the principle just explained, it would follow that the same degree of intercourse could be kept up in England in a space of sixty-four square miles, which in France could be maintained only within twenty-five square miles. Since the establishment of railways the average speed upon these lines of communication, on most parts of the Continent and in America, is fifteen miles an hour. By this improvement, so far as it has been carried, as compared with diligences, the area of practical communication, or, what is the same, of the diffusion of the population compatible with a given degree of intercourse, has been augmented in the ratio of the square of five to the square of fifteen; that is, in a ratio of twenty-five to two hundred and twenty-five. In other words, the same degree of intercourse can be maintained by means of the present railways within an area of two hundred and twenty-five square miles, as could be previously maintained by diligences within an area of twenty-five square miles.

But in England, where the average speed of railway transit is much greater, this power of diffusion is proportionally increased. Assuming the average speed on English railways at twenty-five miles an hour, which is less than its actual amount, the power of intercommunication thus obtained will bear to that obtained on the Continent of Europe where railways are in operation, the ratio of the square of twenty-five to the square of fifteen; that is, of six hundred and twenty-five to two hundred and twenty-five, or of twenty-five to nine.

Thus, the English railways afford the same facilities of communication within an area of twenty-five square miles as is afforded by the continental railways within an area of nine square miles; and thus, by augmenting the speed from fifteen to twenty-five miles an hour, the practical convenience to the public is augmented in the ratio of twenty-five to nine, or very nearly as three to one.

25. The importance of good internal communications in military affairs has long been acknowledged. By the possession of such means of transport as may enable a body of troops, with their arms and ammunition, to be transported promptly and rapidly from one part of the country to another, the standing army,

maintained as well for the purposes of order at home as for the defence of the frontiers, may be diminished in proportion to such facilities.

Instead of maintaining garrisons and posts at points of the country within short distances of each other, it will be sufficient to maintain them at such points that they can, at need, be transported with promptitude to any other point that may be desired. In case of invasion, or any foreign attack on the frontier, by good internal communications, the troops quartered throughout the interior can be rapidly transferred and concentrated upon the point attacked.

If, however, such improvements in the art of transport facilitate the means of maintaining order at home and of defence against a foreign enemy, on the one hand, they also happily, on the other, greatly diminish the probability of a necessity for such expedients. "The natural effect of commerce," says Montesquieu, "is to tend to and consolidate peace." Two nations who trade with each other soon become respectively dependent. If one have an interest to buy, the other has an interest to sell, and a multitude of ties, commercial and social, spring out of their mutual wants.

26. Nothing facilitates and developes commercial relations so effectually as cheap and rapid means of intercommunication. When, therefore, all nations shall be found more intimately connected with each other by these means, they will inevitably multiply their exchanges, and general commerce will undergo great extension, mutual interest will awaken moral sympathies, and will lead to political alliances. After having for ages approached each other only for war, peoples will henceforth visit each other for purposes of amity and intelligence, and old antipathies, national and political, which have so long divided and ruined neighbouring states, will speedily vanish.

But if, in spite of this general tendency towards pacific progress and peace, war should occasionally break out, the improved means of intercommunication will aid in bringing it to a prompt close. A single battle will decide the fate of a country, and the longest war will be probably circumscribed within a few months.

27. The advantages of good means of communication in the diffusion of knowledge, and the increase of civilisation by intellectual means, are not less considerable. While the means of intercommunication are slow, difficult, and costly, great cities have a tendency to monopolise intelligence, civilisation, and refinement. There genius and talent are naturally attracted, while the rural districts are left in a comparatively rude and almost barbarous state. With easy and rapid means of locomotion, however, the

best part of the urban population circulates freely through the country. This interfusion improves and civilises the rural population. The highest intelligence will be occasionally found, both in public and in private, diffusing knowledge and science in the remotest villages. We cannot now take up a London journal without observing announcements of men distinguished in the various branches of knowledge and art, visiting the various towns and villages of the provinces, and delivering their lectures on science, and entertainments and exhibitions in the fine arts. So rapid are the communications, that it is frequently announced that this or that professor or artist will, on Monday evening, deliver a lecture or entertainment in Liverpool, on Tuesday in Manchester, on Wednesday in Preston, on Thursday in Halifax, on Friday in Leeds, and so forth.

28. Nor is this all. The aspirations of the present generation after the spread of knowledge and the advancement of mind, unsatisfied with a celerity of transmission so rapid by the railway, which literally has the speed of the wind, has provoked from human invention still greater wonders. The Electric Telegraph for the transmission of intelligence, in the most literal sense of the term, annihilates both space and time. The interval which elapses between the transmission of a message from London and its delivery at Paris, Brussels, or Berlin, provided the line is uninterrupted, is absolutely inappreciable.

This system is now spreading throughout the whole civilised world. The United States of America are overspread with a network of electricity. The President's message delivered at Washington, was transmitted from thence to St. Louis, on the confines of the state of Missouri, a distance of about 1200 miles, in an hour. The news from Europe arriving at Boston by the Cunard steamers, is often transmitted to New Orleans, over almost the entire territory of the United States from north to south, a distance of nearly 2000 miles, in less time than would be necessary to commit it to paper. Even the small delay that now exists arises, not from any imperfection in the instrument of transmission, but merely from the line of electric communication being interrupted from point to point, and transferred from one system of telegraphs to another, at several intermediate stations. After improvements shall remove such delays as these, we shall probably see intelligence conveyed in an instant over a quadrant of the globe.

29. But if we would seek for a striking illustration of the effects of the rapid transmission of intelligence by the combination of all the various expedients supplied by science to art, it is in the practice of Journalism that we are to look for them, and more especially in

the great enterprises of the London newspapers. The proprietors of a single morning journal are able to maintain agencies, for the transmission of intelligence to the central office in London, in all the principal cities of Europe, besides roving correspondents wherever the prevalence of war, revolution, or any other public event excites a local interest. These various agents or "correspondents" as they are called, not only transmit to the centre of intelligence in London regular despatches by the mails, but also, on occasion of emergency, by special couriers.

These despatches are first received by an agent at Dover, by whom they are forwarded to London by a special messenger. But in cases where intelligence arrives of adequate importance, it is transmitted from the principal continental cities direct to London, in an abridged form, by the electric telegraph, thus anticipating the detailed despatches by many days. Within two hours of its arrival the intelligence is in the hands of the London public.

That portion of the journal intended for the provinces is sent to press at 3 A.M.; and by the activity of the editors, reporters, and compositors, all of whom work during the night, it includes not only the detailed reports of the Houses of Parliament, which often sit to a late hour in the morning, but also the foreign news, as above explained, by electric telegraph. This earliest impression is printed and delivered to the newsvenders, in sufficient time to be despatched to the provinces by the early railway trains, and it is thus delivered at all the stations along the road.

The part of the impression intended for London circulation is worked off and delivered later.

Thus we see that, by these combinations of enterprise, intellectual and material, the intelligence which arrives in London at 3 A.M., is written, composed, printed, and distributed within a radius of one hundred miles round London, and in the hands of the population before their customary hour of breakfast.

Even before the present improved methods of transport were brought into operation, wonders in this way were effected.

Thus, in some cases where debates of adequate public interest took place in Parliament in the evening, the evening mails (for there were then no other) carried to the provinces the first part of an important speech, reported and printed before the remaining part was spoken. Thus it was related that the commencement of Mr. (since Lord) Brougham's celebrated speech on the reform of the laws was read at tea-tables twenty miles from London before he had pronounced the peroration.

Few of the numerous readers of newspapers have the least idea of the immense commercial, social, and intellectual powers wielded, and benefits conferred, by these daily publications, a large portion of which influence is to be ascribed to the cheapness, promptitude, and rapidity with which they are transmitted from the capital to all parts of the country.

It is well known that the average number of copies of the most widely circulating London journal, which are daily issued, amounts at present to more than forty thousand. Each of these forty thousand copies, according to common estimation, passes under the eyes, upon an average, of at least ten persons. Thus we have four hundred thousand daily readers of one organ of information and intelligence. But the effects do not end there. These four hundred thousand *readers*, long before the globe completes a revolution on its axis, become four hundred thousand *talkers*, and have vastly more than four hundred thousand *hearers*. Thus they spread more widely by the ear the information, the arguments, and the opinions they have received through the eye. We shall certainly not be overstating the result if we assume, that this influence of a single journal, directly and indirectly, reaches daily a million of persons.

LOCOMOTION AND TRANSPORT,

THEIR INFLUENCE AND PROGRESS.

CHAPTER II.

RETROSPECT OF THE PROGRESS OF TRANSPORT.

1. Of the first construction and improvement of roads and carriages.—2. Roads do not exist in more than two-sevenths of the inhabited parts of the globe.—3. Roman and Egyptian roads.—4. Roads constructed by order of Semiramis.—5. Internal communication in ancient Greece.—6. Roads of the Phœnicians and Carthaginians.—7. Roman military roads.—8. Commercial intercourse during the middle ages.—9. Influences of the crusades on the art of transport.—10. Roads and intercommunication on the Continent to the middle of the seventeenth century.—11. System of roads projected by Napoleon.—12. Improvement in internal communication after the peace of 1815. roads of France.—13. First roads in England, those made by the Romans.—14. Watling Street, Ermine Street, Fosse-way and Ikenald.—15. First attempts to improve roads in Great Britain in reign of Charles the Second.—16. Transport in Scotland to the middle of the eighteenth century.—17. Slowness of travelling in Scotland.—18. Arthur Young's account of the roads in England in 1770.—19. Comparison between cost and speed of former and present modes of transport.—20. Origin of railways in England.—21. Their immediate effects.—22. Progress of the construction.—23. Their extent in 1852.—24. Capital absorbed by them.—25. Labour employed by them.

LOCOMOTION AND TRANSPORT.

1. In the first attempts at an interchange of the products of industry, which mark the incipient commerce of a people emerging from barbarism, human labour and the strength of the inferior animals, applied in the most rude and direct manner to transport, are all the means brought into play. The pedlar and the pack-horse perform all the operations of interchange which take place in an infant society. Pathways are formed over the natural surface of the ground, in a course more or less direct, between village and village. The beds of streams following, by the laws of physics, the lowest levels, serve as the first indication to the traveller how to avoid steep acclivities, and, by deviating from the most direct and shortest course, to obtain his object with a diminished amount of labour.

As industry is stimulated and becomes more productive, invention is brought more largely into play, and these rude expedients are improved. Wheel carriages are invented, but the earliest theatre of their operations is the immediate surface of the soil from which the products of agriculture are raised. They are used to gather and transport these to a place where they may be sheltered and secured.

But to enable wheel carriages to serve as the means of transport between places more or less distant, the former horse-paths are insufficient. A more uniform and level surface, and a harder substratum, become indispensable. In a word, a Road, constructed with more or less perfection, is necessary.

These roads, at first extremely rude and inartificial, and rendered barely smooth and hard enough for the little commerce of an infant people, are gradually improved. The carriages, also, which serve as the means of transport undergo like improvement, until, after a series of ages, that astonishing instrument of commerce, the modern road, results, which is carried on an artificial causeway, and reduced, at an enormous expense, to a nearly level surface by means of vast excavations, extensive embankments, bridges, viaducts, tunnels, and other expedients supplied by the skill and ingenuity of the engineer.

Between the pack-horse, used in the first stages of growing commerce, and such a road with its artificial carriages, there is a prodigious distance. The first step, from the pack-horse to the common two-wheel cart, was, in itself, a great advance.

It is calculated that a horse of average force, working for eight or ten hours a day, cannot transport on his back more than two hundredweight, and that he can carry this at the rate of only twenty-five miles a day over an average level country. The same horse, working in a two-wheel cart, will carry through the same distance per day twenty hundredweight, exclusive of the weight of the cart. By this simple expedient, therefore, the art of transport was improved in the ratio of one to ten; in other words, the transport which before was effected at the cost of ten pounds, was, with this expedient, reduced to the cost of one pound.

2. The adoption of expedients for the maintenance of commerce so obvious as roads, would seem to be inevitable among a people who are not actually in a state of barbarism. Nevertheless, we find that not only was the construction of good roads for commercial purposes of comparatively recent date, but that, even at the present day, a very large portion of that part of the world called civilised, is unprovided with them. With the exception of certain parts of Europe, the French colony of Algeria, and the United States, the entire surface of the world is still without this means of intercourse.

It is calculated that, of the entire inhabited part of the globe, roads do not exist in more than *two-sevenths*. The extensive empire of Russia, with the exception of one or two main communications, such as that between Petersburg and Moscow, is without them. In general, the only practicable communications through this vast territory are effected in winter on the surface of the frozen snow by sledges. On the return of summer, when the snow has disappeared, the communications become extremely difficult, slow, and expensive. Spain is scarcely better supplied with roads than Russia, nor do we find much improvement in the practice of transport in Italy. Until recently, Corsica possessed no communications of this sort; horses and mules were the common means of communication and interchange in that island until the French government constructed some roads.

3. The roads constructed by the Romans and Egyptians will probably be referred to as instances of an early advance in this art. But these great monuments of antiquity, though serving incidentally, to some extent, as means of commerce, were constructed for exclusively military purposes.

4. The most ancient roads which are recorded in history, are those constructed by order of Semiramis, throughout the extent of her empire. It would seem, however, that the commerce of that day did not find these communications suitable to its objects; for it is certain that, at the epoch at which Tyre and Carthage were signalised for their enterprise, their commerce was almost exclusively carried on by the coasting navigation of the Mediterranean.

5. Notwithstanding the advanced stage to which civilisation had arrived in Greece, the means of internal communication in that country remained in a state of great imperfection. This may in

part be explained by the multitude of small states which formed that confederation, by their conflicting interests, and their want of any moral or social sympathies. The common sentiment of nationality slumbered, except when it was awakened by the strong stimulus of foreign attack. The intercourse between one centre of population and another was then very restrained, and although the public ways were placed under the protection of the gods, and the direction of the most considerable men of the respective states, they were suffered to fall into neglect. The exigencies of internal commerce were never sufficiently pressing to excite the people to contribute to the maintenance of good means of intercommunication and exchange.

6. The earliest roads which were really rendered conducive to the purposes of commerce, on any considerable scale, were those constructed by the Phenicians and Carthaginians. To the latter is ascribed, by Isidore, the invention of paved roads.

7. When imperial Rome attained the meridian of her power, and her empire extended over a large portion of Europe and Asia, colossal enterprises were entered upon for the construction of vast lines of communication, extending over the immensity of her territory. These roads, however, like those of the Egyptians, were constructed without the slightest view to commercial objects. It concerned imperial Rome but little, that her provinces should be united by commercial or social interests. What she looked to was to be enabled to convey with celerity her powerful legions at all times from one extremity of her dominions to another. With this purpose, she availed herself of her vast resources to construct those military roads, intersecting her territory, the remains of which have excited the admiration of succeeding generations.

The first of these great monuments of the enterprise and art of the Roman people were those so well known by the names of the Via Appia, the Via Aurelia, and the Via Flaminia. Under Julius Caesar, communications were made by paved roads between the capital of the empire and all the chief towns. During the last African war, a paved road was constructed from Spain, through Gaul, to the Alps. Subsequently similar lines of communication were carried through Savoy, Dauphiné, Provence, through Germany, through a part of Spain, through Gaul, and even to Constantinople.

Asia Minor, Hungary, and Macedonia were overspread with similar lines of communication, which were carried to the mouths of the Danube. Nor was this vast enterprise obstructed by the intervention of seas. The great lines which terminated on the shores of continental Europe were continued at the nearest points of the neighbouring islands and continents. Thus, Sicily, Corsica, Sardinia, and England, and even Africa and Asia, were intersected and penetrated by roads, forming the continuation of the great European system.

These colossal works were not paths rudely prepared for the action of the feet of horses and the wheels of carriages, by merely removing the natural asperities from the surface of the soil. They were constructed, on the contrary, on principles in some respects as sound and scientific as those which modern engineering has supplied. Where the exigencies of the country required it, forests were felled, mountains excavated, hills levelled, valleys filled up, chasms and rivers bestridden by bridges, and marshes drained, to an extent which would suffer little by comparison with the operations of our great road-makers of modern times.

On the fall of the Empire, these means of communication, instead of subserving the purposes of the commerce of the people through whose territory they were carried, were, for the most part, destroyed. When the barbarians conquered Rome, and a multitude of states were formed from its ruins, the victors shut themselves up and fortified themselves in these several states, as an army does in a citadel; and, far from constructing new roads, they destroyed those which had already existed, as a town threatened with siege breaks those communications by which the enemy may approach it.

8. From this epoch through a long series of ages, the nations of Europe, animated only by a spirit of reciprocal antagonism, thought of nothing but war, and entered each other's territories only for the purposes of conflict. The history of the intercommunications of nations during the middle ages is only a history of their wars.

When Europe emerged from this state, and when commerce began to force itself into life, its operations were in a great measure monopolised by Jewish and Lombard merchants, who carried them on subject to the greatest difficulty and danger.

The provincial nobles and lords of the soil, through whose possessions the merchant necessarily passed in carrying on the internal commerce of the country, were nothing better than highway robbers. They issued with their bands from their castles and arrested the travelling merchant, stripping him of the goods which he carried for sale.

The sovereigns of France endeavoured in vain, by penal enactments, to check this enormous evil. Dagobert I. established a sort of code to regulate the public communications through his dominions, and decreed heavy fines against such provincial lords as might obstruct the freedom of communication, by interrupting or plundering travellers. These decrees, however, remained a dead letter, no adequate power in the state being able to carry them into practical effect.

Under the successors of Charlemagne, this abuse, which it was found impossible to repress, was, in some measure, recognised and regularised. Tolls of limited amount were allowed to be exacted by the local proprietors from those who passed through the provinces for purposes of trade, on the condition that such travellers or merchants should be otherwise unmolested.

The prevalence of all these vexatious impediments soon rendered intercommunication by land almost impracticable. The roads, such as they were, became accordingly deserted, and were suffered to fall into utter disrepair. During a series of ages, internal communication and internal commerce became almost suspended; a journey even of a few leagues being regarded as a most serious and dangerous undertaking.

9. The Crusades had a favourable influence on the art of transport. The population of Western and Northern Europe became by them acquainted with the productions and arts of the East. New desires were excited and new wants created. Commerce was thus stimulated, and greater facility of intercourse becoming necessary, governments were forced to adopt expedients for the security of the traveller.

The same difficulties and dangers did not, however, affect navigation. We find this art developed in a much higher degree than that of internal commerce. Hence arose the disproportionate commercial opulence of maritime people. The British, the Dutch, and the Portuguese rose into immense commercial importance, as well as the Genoese, the Tuscans, and the Venetians.

10. Even so late as the middle of the seventeenth century, the roads throughout the Continent continued in a condition which rendered travelling almost impracticable.

They are described by writers of this epoch as being absolute sloughs. Madame de Sevigny, writing in 1672, says, that a journey from Paris to Marseilles, which by the common roads of the present day is effected in less than sixty hours, required a whole month.

Besides the material obstacles opposed to the growth of internal commerce on the Continent by the want of roads in sufficient number, and the miserable state of those which did exist, other impediments were created and difficulties interposed by innumerable fiscal exactions, to which the trader was exposed, not only in passing the confines of different states, but even in going from province to province in the same state, and in passing through almost every town and village. Hence the cost of every commodity was enormously enhanced, even at short distances from the place of its production.

11. The disorganisation of society and the destruction of the institutions of feudalism which followed the French Revolution of 1789, caused some improvement in the means of internal commerce in Europe, and would have caused a much greater development in this instrument of civilisation, but for the wars which immediately succeeded that political catastrophe, and which only terminated with the battle of Waterloo.

Indeed Napoleon, conscious of the vast importance of a more complete system of roads, had actually projected one, which he intended to spread over Europe. His fall, however, intercepted the realisation of this magnificent design, and the *Simplon* remains as the only monument of his glory in this department of art.

After the re-establishment of peace, the nations of Europe, directing their activity to industry and commerce, soon became impressed with the necessity of effecting a great improvement in the means of internal communication. Western Europe, accordingly, soon began to be covered with roads and canals. The obstructions arising from fiscal causes, if not removed, were greatly diminished.

The advance made by France especially in this department, is deserving of notice. That country possesses at present four or five times the extent of roads which were practicable under the Empire; a sum of nearly four millions sterling was, until lately, expended annually upon the completion and maintenance of these great lines of communication.

The roads of France consist of three classes; the first, until the late revolution, were called *royal roads*, and are now called *national roads*. These are the great arteries of communication carried from one chief town to another throughout the territory, and being used indifferently, or nearly so, by the whole population, are constructed and maintained at the general expense of the nation. The second class are *departmental roads*, or what would be called in England *county roads*. These are chiefly the branches running into the royal roads, by which the local interests of the departments are served, and are accordingly maintained at the expense of the departments. Finally, the third class is called *vicinal roads*, which would correspond to our *parish roads*.

The rate at which these improved communications have contributed to augment the internal commerce and national wealth, may be estimated in some degree from the statistical results which have been published. In 1810, the various stage-coach establishments in Paris transported each day from the capital into the departments, two hundred and twenty passengers, and twenty-one tons of merchandise. Before the establishment of railways, they transported nearly one thousand passengers and forty-five tons of merchandise. Thus the passengers were augmented in a fourfold, and the merchandise in a twofold proportion.

12. In 1815, the length of roads in operation in France was as follows: there were three thousand leagues of royal roads, and two thousand leagues of departmental roads. In 1829, there were four thousand two hundred and five leagues of royal roads, and three thousand leagues of departmental roads. In 1844, there were eight thousand six hundred and twenty-eight leagues of royal roads, and nine thousand one hundred and forty-six leagues of departmental roads, independently of twelve thousand leagues of vicinal roads. Thus, it appears that between 1815 and 1844, the total length of roads of the first and second classes was augmented from five thousand leagues to nearly eighteen thousand, or in the proportion of three and a half to one.

13. Although the practice of road-making in England attained a certain degree of perfection at a much earlier period than in other parts of Europe, and the United Kingdom was overspread with a noble network of internal communications, while continental Europe remained in a comparatively barbarous condition, the art of transport nevertheless, even in England, remained for a long series of ages incalculably behind what would seem to be the commercial wants of the population.

The first English roads of artificial construction were those made by the Romans, while England was a province of that empire. The island was then intersected by two grand trunk roads running at right angles to each other, the one from north to south, and the other from east to west.

These main lines were supplied with various branches, extending in every direction which the conquerors found it expedient to render accessible to their armies.

14. The Roman road called *Watling Street* commenced from Richborough, in Kent, the ancient Rutupial, and, passing through London, was carried in a north-westerly direction to Chester. The road called *Ermine Street* commenced from London, and, passing through Lincoln, was carried thence through Carlisle into Scotland. The road called the *Fosse-way* passed through Bath in a direction N.E., and terminated in the Ermine Street. The road called *Ikenald* extended from Norwich in a southern direction to Dorsetshire.

But these great works, at the date of their construction, exceeded the wants of the population, who, unconscious of their advantage, allowed them to fall into neglect and disrepair. Nor were any new roads in other or better directions constructed. For a succession of ages the little intercourse that was maintained between the various parts of Great Britain was effected almost exclusively by rude footpaths, traversed by pedestrians, or at best by horses.

These were carried over the natural surface of the ground, generally in straight directions, from one place to another. Hills were surmounted, valleys crossed, and rivers forded by these rude agents of transport, in the same manner as the savages and settlers of the backwoods of America or the slopes of the Rocky Mountains now communicate with each other.

15. The first important attempt made to improve the communications of Great Britain took place in the reign of Charles II. In the sixteenth year of the reign of that monarch was established the first turnpike road where toll was taken, which intersected the counties of Hertford, Cambridge, and Huntingdon. It long remained, however, an isolated line of communication; and it was little more than a century ago that any extensive or effectual attempts were made, of a general character, to construct a good system of roads through the country.

16. Until the middle of the eighteenth century, most of the merchandise which was conveyed from place to place in Scotland was transported on pack-horses. Oatmeal, coals, turf, and even hay and straw, were carried in this manner through short distances; but when it was necessary to carry merchandise between distant places, a cart was used, a horse not being able to transport on his back a sufficient quantity of goods to pay the cost of the journey.

17. The time required by the common carriers to complete their journey seems, when compared with our present standard of speed, quite incredible. Thus, it is recorded that the carrier between Selkirk and Edinburgh, a distance of thirty-eight miles, required a fortnight for his journey, going and returning. The road lay chiefly along the bottom of the district called *Gala-water*, the bed of the stream, when not flooded, being the ground chosen as the most level and easy to travel on.

In 1678, a contract was made to establish a coach for passengers between Edinburgh and Glasgow, a distance of forty-four miles. This coach was drawn by six horses, and the journey between the two places, to and fro, was completed in six days. Even so recently as the year 1750, the stage-coach from Edinburgh to Glasgow took thirty-six hours to make the journey. In 1849, the same journey was made, by a route three miles longer, in one hour and a half!

In the year 1763 there was but one stage-coach between Edinburgh and London. This started once a month from each of these cities. It took a fortnight to perform the journey. At the same epoch the journey between London and York required four days.

In 1835 there were seven coaches started daily between London and Edinburgh, which performed the journey in less than forty-eight hours. In 1849, the same journey was performed by railway in twelve hours!

In 1763, the number of passengers conveyed by the coaches between London and Edinburgh could not have exceeded about twenty-five *monthly*, and by all means of conveyance whatever did not exceed fifty. In 1835 the coaches alone conveyed between these two capitals about one hundred and forty passengers *daily*, or four thousand monthly. But besides these, several steam-ships, of enormous magnitude, sailed weekly between the two places, supplying all the accommodation and luxury of floating hotels, and completing the voyage at the same rate as the coaches, in less than forty-eight hours.

As these steam-ships conveyed at least as many passengers as the coaches, we may estimate the actual number of passengers transported between the two places monthly at eight thousand. Thus the intercourse between London and Edinburgh in 1835 was one hundred and sixty times greater than in 1763.

At present the intercourse is increased in a much higher ratio, by the improved facility and greater cheapness of railway transport.

18. Arthur Young, who travelled in Lancashire about the year 1770, has left us in his Tour the following account of the state of the roads at that time. "I know not," he says, "in the whole range of language, terms sufficiently expressive to describe this infernal road. Let me most seriously caution all travellers who may accidentally propose to travel this terrible country to avoid it as they would the devil, for a thousand to one they break their necks or their limbs by overthrows or breakings down. They will here meet with ruts, which I actually measured, four feet deep, and floating with mud, only from a wet summer. What, therefore, must it be after a winter? The only mending it receives is tumbling in some loose stones, which serve no other purpose than jolting a carriage in the most intolerable manner. These are not merely opinions, but facts; for I actually passed three carts broken down in these eighteen miles of execrable memory."

And again he says (speaking of a turnpike road near Warrington, now superseded by the Grand Junction Railway,) "This is a paved road, most infamously bad. Any person would imagine the people of the country had made it with a view to immediate destruction! for the breadth is only sufficient for one carriage; consequently it is cut at once into ruts; and you may easily conceive what a break-down, dislocating road, ruts cut through a pavement must be."

Nor was the state of the roads in other parts of the north of England better. He says of a road near Newcastle, now superseded by a railway, "A more dreadful road cannot be imagined. I was obliged to hire two men at one place to support my chaise from overturning. Let me persuade all travellers to avoid this terrible country, which must either dislocate their bones with broken pavements, or bury them in muddy sand. It is only bad management that can occasion such very miserable roads in a country so abounding with towns, trade, and manufactures."

Now, it so happens that the precise ground over which Mr. Young travelled in this manner less than eighty years ago is at present literally reticulated with railways, upon which tens of thousands of passengers are daily transported, at a speed varying from thirty to fifty miles an hour, in carriages affording no more inconvenience or discomfort than Mr. Young suffered in 1770, when reposing in his drawing-room in his arm-chair.

19. Until the close of the last century, the internal transport of goods in England was performed by waggon, and was not only intolerably slow, but so expensive as to exclude every object except manufactured articles, and such as, being of light weight and small bulk in proportion to their value, would allow of a high rate of transport. Thus the charge for carriage by waggon from London to Leeds was at the rate of 13*l.* a ton, being 13½*d.* per ton per mile. Between Liverpool and Manchester it was forty shillings a ton, or 15*d.* per ton per mile. Heavy articles, such as coals and other materials, could only be available for commerce where their position favoured transport by sea, and, consequently, many of the richest districts of the kingdom remained unproductive, awaiting the tardy advancement of the art of transport. Coals are now carried upon railways at a penny per ton per mile, and, in some places, at even a lower rate. Merchandise, such as that mentioned above, which was transported in 1763 at from 14*d.* to 15*d.* per mile, is now carried at from 3*d.* to 4*d.*, while those sorts which are heavier in proportion to their bulk are transported at 2½*d.* per ton per mile.

But this is not all: the waggon transport formerly practised was limited to a speed which in its most improved state did not exceed twenty-four miles a day, while the present transport by railway is effected at the rate of from twelve to fourteen miles an hour.

20. When we look back upon the state in which every part of the civilised world was placed in relation to this vital element of social and commercial progress, this standard and test, as it may be justly called, of civilisation at an epoch so recent as the first year of the present century, and compare it with the present condition not of England only, but of Europe and North America, we cannot fail to be struck with the incalculable amount of benefit to the human race that must result from the extraordinary energy with which the discoveries and resources of science have been applied to the improvement of this instrument of civilisation within the brief interval of twenty-four years, for it is not more since the date of the commencement of railway transport in this country which took the lead in that, as in so many other improvements in the arts of life.

21. In 1830, the first railway for general traffic in passengers and goods between Liverpool and Manchester was opened; and immediately, of the thirty stage-coaches which had previously run daily between Liverpool and Manchester, one only remained on the road; and that was supported solely by passengers to intermediate places not lying in the direction of the railway.

The comparatively low fares and extraordinary expedition offered by the railway had the effect which might have been expected. Previously, the number of travellers daily, by the coaches, was about five hundred; it was immediately augmented above three-fold. Sixteen hundred passengers per day passed between these towns. If the traffic in passengers exceeded all anticipation, the transport of goods, on the contrary, fell short of what was expected. The canal lowered its tariff to the level of the railway charges and increased its speed and its attention to the accommodation of customers. The canal, moreover, winding through Manchester, washed the walls of the warehouses of the merchants and manufacturers. At the other end it communicated directly with the Liverpool docks. The goods were therefore received directly from the ship, and delivered directly to the warehouse, or *vice versâ;* without the cost, delay, and inconvenience of intermediate transhipment and cartage. These considerations went far to counterbalance the superior speed of the railway transit for goods; yet, notwithstanding this inconvenience and obstruction, the company soon found themselves carriers of merchandise at the rate of a thousand tons per day.

Thus, the problem of the rapid transport of passengers by steam on railways was solved in 1830, and the profitable character of the enterprise soon became apparent. Dividends of 10 per cent. were declared, and the shares were greedily bought up at 120 per cent. premium. Then followed in rapid succession those results which must necessarily have ensued. Other lines of railway, connecting the chief centres of population and industry with the metropolis, and with each other, were projected. In the four years which elapsed from 1832 to 1836, about 450 miles of railway were completed, and 350 miles were in progress of construction.

22. From 1836 to the present time the construction of these great lines of intercommunication in the United Kingdom has proceeded at a rate of progress of which no previous example has ever been recorded in the history of the industrial arts in any country. From the official reports presented to Parliament, it appears that the whole extent of railway communication open for traffic in the United Kingdom at the end of 1852 was 7336 miles, which were distributed in the different portions of the kingdom in the following proportions:—

In England and Wales	5650 miles.
In Scotland	978
In Ireland	708
Total in the United Kingdom . .	7336 miles open for public traffic.

It further appears from these reports that, at the close of 1852, the legislature had authorised the construction of a total length of railway (including the above 7336 miles) amounting to 12561 miles, of which 676 miles had been abandoned by the companies which had originally undertaken them. Thus the account of the total amount authorised by Parliament, to the end of 1852, stood thus:—

Constructed and in operation. . .	7336 miles.
In progress or intended to be commenced	4549
Abandoned	676
	12561 miles.

23. The following table, taken from the report of the Committee of the Privy Council, dated August, 1853, will exhibit the rate at which the railway projects were sanctioned by Parliament, and the rate at which their execution has progressed up to the end of 1852:—

Table showing the Proportion of Railways authorised previous to the end of 1843, and in each succeeding Year, opened for Traffic during each Year, and the proportion remaining to be completed at the end of 1852; also, showing the Total Length of Railway opened for Traffic in each Year since 1843.

—	LENGTH OF LINE OPENED.										Total Length of Line opened to December, 1852.	Length of Line authorised at end of 1843. and during each subsequent year.	Decrease by Abandonment, Deviation, &c., under authority of subsequent Acts.	Length of Line after Reductions made in consequence of Abandonment, Deviation, &c., under the authority of Acts passed subsequent to 1843.	Length of Line remaining to be made.
	Previously to December, 1843.	During 1844.	During 1845.	During 1846.	During 1847.	During 1848.	During 1849.	During 1850.	During 1851.	During 1852.					
Of Lines authorised previously to December, 1843	2036	204	131	16	2	1	..	..	..	..	2390	2390	..	2890	..
Of Lines authorised in . . . 1844	..	..	159	366	142	118	3	4	..	..	792	805	..	805	13
1845	..	..	6	224	573	604	311	213	65	106	2102	2700	33	2667	565
1846	..	..	..	..	84	403	501	379	122	288	1777	4538	478	4060	2283
1847	..	..	..	..	2	56	45	26	71	10	210	1354	160	1194	984
1848	..	..	..	..	..	..	7	..	7	16	30	371	5	366	336
1849	..	..	..	..	..	..	2	1	..	..	3	16	..	16	13
1850	..	..	..	..	..	..	..	2	4	..	6	8	..	8	2
1851	..	..	..	..	..	..	..	..	..	15	15	135	..	135	120
1852	..	..	..	..	..	..	..	..	..	11	11	244	..	244	233
Total . .	2036	204	296	606	803	1182	869	625	269	446	7336	12561	676	11835	4549

24. Nothing in the progressive development of this vast national enterprise is more surprising than the amount of capital raised and expended upon it, and the rapidity and facility with which it was obtained.

The following statement, also taken from the official reports, will illustrate this:—

Total capital raised by shares and loans up to the end of 1848.	£200,173058
Total capital similarly raised in 1849. . .	29,574720
Ditto. . . 1850. . .	10,522967
Ditto. . . . 1851. . .	7,970151
Total capital raised up to the end of 1851	£248,240896

Of the sum of 248 millions, which had been expended before the 1st January, 1852, a part had been absorbed by the lines which were in process of construction, but had not yet been opened. Against this, however, there remained an amount of capital still to be expended on the lines already open. On most of the more recently opened railways, the stations were still incomplete; in some cases, depots, workshops, and other permanent buildings had not even been commenced. The full complement of the locomotive and rolling stock had not been provided. In the absence of exact data then, if these latter expenses be placed against the former, the entire capital of 248 millions may be placed to the account of 7336 miles open for traffic; which would give an average expense of construction, including the locomotive and carrying stock, and the workshops and depots for its repair, &c., of 33840*l.* per running mile.

25. The extent to which these enterprises employed the industry of the country may be judged from the following results of the reports:—

It appears that in 1848 a quarter of a million of persons were employed on the railways of the United Kingdom; and if it be considered that each of these must have contributed to the support, on an average, of one or more other persons, it will follow, that this vast enterprise must have, at that epoch, supplied means of living to at least two per cent. of the entire population of these countries.

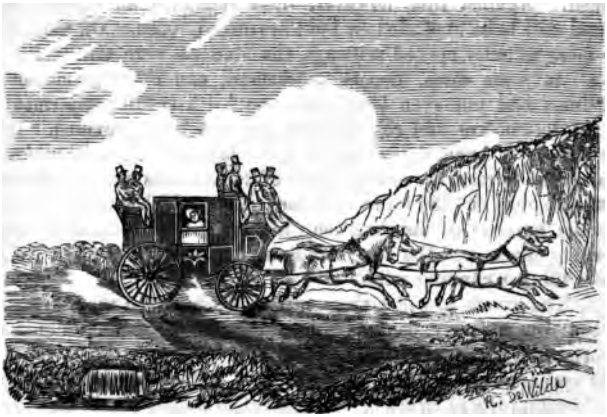
It further appears that, on the 30th June, 1852, there were employed

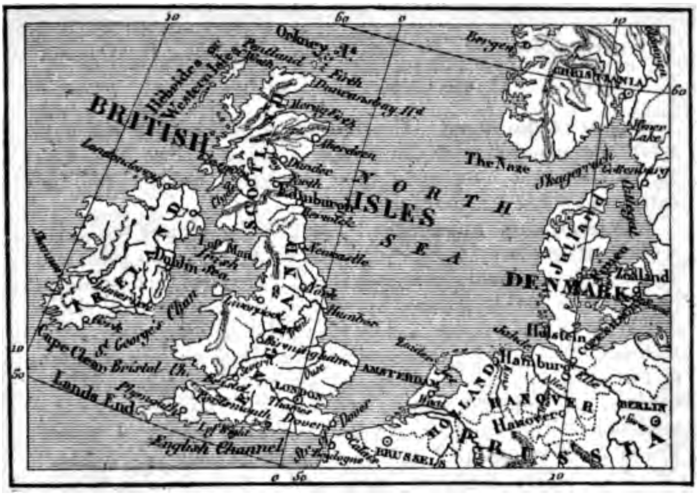
On the railways open for traffic	67601
On the railways in progress of construction	35935
	103536

It follows, therefore, that from 1848, to June, 1852, about

150000 persons have been dismissed from the direct employment of the railway companies, and who must now be obtaining support from other occupations. It is, however, certain that a large increase of the demand for labour has been produced by the creation and operation of railway traffic, such as that which arises and must arise from the establishment of founderies, carriage, and engine building, and other branches of railway business, not only in the United Kingdom, but in other countries which are to a great extent supplied by British industry.

We shall on another occasion notice the progress of locomotion by railway in other countries.





I.—UNITED KINGDOM, DENMARK, &c.

THE SURFACE OF THE EARTH,

OR FIRST NOTIONS OF GEOGRAPHY.

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CHAPTER I.

The Surface of the Earth : 1. Origin of the name.—2. Preliminary knowledge.—3. The distribution of land and water.—4. The undulations of the terrestrial surface.—5. Geographical Terms : 6. Islands.—7. Continents.—8. Peninsulas.—9. Isthmuses.—10. Promontories.—11. Capes and headlands.—12. The relief of the land.—13. Plains and lowlands.—14. Plateaux and table-lands.—15. Hills.—16. Mountains.—17. Systems or chains of mountains.—18. Oceans.—19. Seas.—20. Gulfs.—21. Bays.—22. Straits.—23. Channels.—24. Roads and roadsteads.—25. Banks and sand-banks.—26. Reefs.—27. Soundings.—28. Lakes.—29. Rivers.—30. The bed of a river.—31. The banks of a river.—32. Tributaries.—33. Vallies.—34. Watersheds.—35. Delta.—36. Estuaries.—37. Friths. The Great Eastern Continent : 38. Its extent and limits.—39. Its divisions. 40. The Mediterranean.—41. Relief.—42. Its northern belt.—43. The southern belt.—44. Prevailing mountain chains.—45. Outlines of Europe.—46. White Sea.—47. Norway and Sweden.—48. British Isles.—49. France.—50. Spain and Portugal.—51. Italy.—52. Sicily.—53. Greece.—54. Archipelago.—55. Dardanelles and Bosphorus.—56. The Black Sea.—57. Sea of Azof.—58. The Caspian.

—59. Africa.—60. Its climatological zones.—61. The Tell and Sahara.—62. Valley of the Nile.—63. The central belt.—64. The fourth zone.—65. The southern zone.—66. The coasts.

1. **Origin of the name.**—The division of general instruction to which the description of the surface of the earth has been consigned, is called *Geography*, from two Greek words γῆ (ge) the earth, and γράφω (grapho) I describe.

2. **Preliminary knowledge.**—The globular form of the earth,—its rotation every twenty-four hours on its axis,—its poles and equator, the imaginary lines upon it called meridians and parallels,—latitudes and longitudes by which the positions of places relatively to the equator and to each other are expressed,—the methods of ascertaining these positions for all places,—the division of the globe into the northern and southern hemispheres by the equator, and into the eastern and western hemispheres by the meridian of Greenwich,—have been severally explained in our Tracts on the "Earth" and on "Latitudes and Longitudes." All these points constitute indispensable preliminaries to any clear or satisfactory knowledge of geography, and we shall therefore assume in the present Tract that the reader has already become familiar with them.

3. **The distribution of land and water** on the surface of the globe forms the first step in geographical knowledge. The entire terrestrial surface measures about two hundred millions of square miles. Very nearly three-fourths of this is covered with water. The whole surface would be so if it were uniformly level. But being unequal, some parts being more elevated, and others less so, the water, in obedience to the law of gravity, settles upon the lower levels, leaving the more elevated parts dry. It is thus that the Almighty has "gathered the waters into one place," and made "the dry land appear," and to the "gathering of waters" has given the name *Seas*.

Land is therefore nothing more than the summits and elevated plateaux of vast mountains, the bases of which are at the bottom of the water which thus covers three-fourths of the surface.

4. **The undulations of the terrestrial surface** are extremely diversified and irregular, and since the distribution and outlines of the land are determined by them, the latter are equally various and complicated. The declivities by which these elevated parts slope downwards, determine the lines according to which the waters of the sea wash them, and these outlines give those peculiar forms and characters to the land, the description and knowledge of which forms a large part of geography. A system of terms has been invented by which these various forms are expressed and classified.

5. **Geographical Terms.**—Although these terms do not always admit of rigorous definition, and their application is often more or less arbitrary, they are nevertheless eminently useful, and indeed essential to the acquisition of a general knowledge of geography.

6. **Islands** are tracts of land surrounded by water. The term, however, is generally limited to tracts of not very considerable extent. When very small they are often called *isles* or *islets.*

The distribution of islands is not uniform. In some parts they are thickly clustered together within a limited extent of water. A part of the sea thus sprinkled with islands is called an archipelago,* a name which was first applied to the Ægæan Sea, which separates Greece from Asia Minor, but which has been generalised so as to signify any portion of the waters of the globe having a like character.

Islands are found for the most part in the immediate vicinity of the coasts of much larger tracts of land. In this case they are evidently parts of such tracts, separated from them only by valleys, so low that the sea flows through them. Islands, however, are also sometimes found in groups, sometimes ranged in lines, and sometimes, though not frequently, rising singly and isolated in the midst of the ocean.

7. **Continents** are tracts surrounded by water, whose magnitude bears a considerable proportion to the entire surface of the globe.

It will be easily understood that this distinction between islands and continents, depending only on their comparative magnitudes, must be arbitrary, so long as no exact limit is assigned at which a tract of land surrounded by water ceases to be an island and becomes a continent.

The tract in the southern hemisphere, called *Australia*, was formerly classed as an island. More recently geographers give it the title of a continent.

Besides this, there are only two continents properly so called on the globe, each of which has vast magnitude, the one lying in the eastern, and the other in the western hemisphere.

The Eastern Continent, sometimes called the *great continent,* includes Europe, Asia, and Africa, each of which has received the name of continent, though the whole forms one continuous tract of land, between any two points of which it is possible to pass without crossing a sea.

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* Etymologists are not agreed upon the origin of this term ; some supposing it to be composed of *ἀρχὸς* (archos), chief, and *πέλαγος* (pelagos), a sea, and others of *Αἴγαιος* (aigaios) and *πέλαγος*, the Ægæan Sea.

The Western or lesser continent consists of North and South America.

The great or eastern continent, having been known to the ancients, is often called the *Old Continent* or the *Old World.*

The western, having been unknown until its discovery by Columbus in the fifteenth century, is often called the *New World.*

8. **Peninsulas** are tracts, nearly, but not altogether, surrounded by water. The name is composed of two Latin words, *pene,* almost, and *insula,* an island.

9. **Isthmuses** are narrow necks, by which two comparatively large tracts are connected together. Isthmus is a Greek word, having the same signification.

The most remarkable examples of an isthmus are presented by the narrow tracts by which Africa is connected with Asia, and South with North America. The former being called the *Isthmus of Suez,* and the latter the *Isthmus of Panama.* Two towns, bearing these names, are built, one upon the former isthmus, on the coast of the Red Sea, and the other upon the latter, on the coast of the Pacific Ocean.

Peninsulas are often thus connected by an isthmus with the mainlands, to which they belong, but not always so. The name peninsula is given to tracts of land which, though partially surrounded by water, are nevertheless connected with the mainland by tracts much too broad to be entitled to the name of isthmus. Examples of this class of peninsular form are numerous, and among them may be mentioned the part of Southern Europe, which includes Spain and Portugal, called the *Spanish Peninsula* (Map 5.); the part of Italy, south of Lombardy and Piedmont, called the *Italian Peninsula*: the southern part of Greece, called the *Hellenic Peninsula* (Map 6); India, and numerous other similar masses of land, projecting in a pointed form into the sea (Map 7).

10. **Promontory** is a name given to a tract of land, of greater or less elevation above the level of the sea, which juts out from a comparatively large extent of land, and which therefore is peninsular in its form. The term, however, is usually applied to tracts of less extent than those which are denominated peninsulas.

11. **Capes and Headlands** are promontories having considerable elevation, so as to be visible from a great distance at sea.

12. **The Relief of the Land** has received different denominations according to its varying elevation above the general level.

13. **Plains and Lowlands** are parts of the land not much raised above the level of the sea, having considerable extent.

Various names are given to such tracts according to the language of the country and their condition in respect to vegetation. Thus an extensive sandy plain, destitute of all vegetation, is called a *Desert;* an example of such a plain on an immense scale is presented by the *Desert of Sahara*, in the North of Africa. Such plains are called *Landes* in France, *Steppes* in Russia, and *Llanos*, *Pampas*, *Selvas*, *Savannahs*, and *Prairies*, according as they are more or less covered with vegetation, in North and South America.

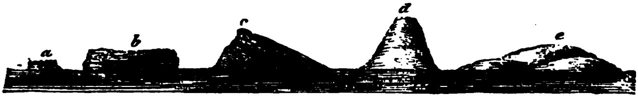


Fig. 1.—Forms of Plateaux, Hills and Mountains.

14. **Plateaux and Tablelands** are extensive level tracts, placed at considerable elevations above the level of the sea, or the general level of the surrounding country, *a b*, fig. 1.

15. **Hills** are elevations not exceeding about 1000 feet in height above the plain at their base, and having an outline variously formed; rounded, *e*, fig. 1.; ridged, *d*, fig. 1, or peaked, as *c*, fig. 1, and fig. 3.

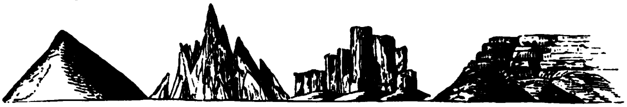
Fig. 2.—Groups of Mountains.

16. **Mountains** are elevations generally exceeding 1000 feet in height, and likewise subject to a similar variety of forms, as shown in fig. 2.

The application of these terms "hills" and "mountains" is very arbitrary, elevations which receive the name of mountains in one place being lower than those called hills in another.

The forms of mountains are very various, and have an important relation to their external structure. Geologists are often able to determine the character of the rocks of which they consist by their outline. Thus, when the outline is characterised by needles rising to considerable elevations, as in fig. 4, the mountainous mass consists of the rocks called Gneiss. Such peaks, which are frequent upon the chain of the Alps, are called *needles*, *teeth*, and *horns*. Mountains are sometimes columnar in their structure, as in fig. 5, resembling fortifications seen from a distance. In this case they are usually formed of calcareous, that is, limestone rocks. Mountains composed of the same rocks also frequently assume the form shown in fig. 6, as if they were cut into steps forming a series of horizontal stages one above the other.

Fig. 3. Fig 4. Fig. 5. Fig. 6.



Various forms of Mountains.

Mountains which assume the peaked or conical form, with a cavity or cup-like depression at their summits, are always of volcanic origin.

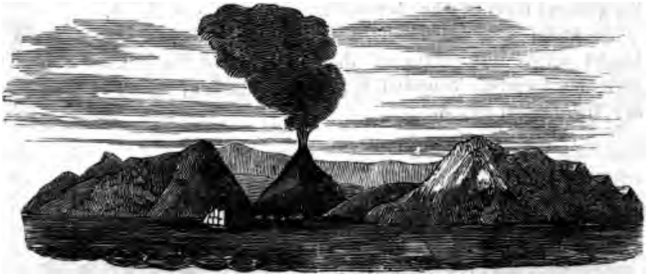


Fig. 7.—Barren Island in Bay of Bengal.

In fig. 7, an example of this is presented in the case of Barren island in the Bay of Bengal, consisting of a volcanic cone, 1848 feet high, which is frequently in a state of eruption, surrounded by other peaks of similar formation.

17. **Systems or Chains of Mountains** consist of series of mountains, of varying elevation and form, which are often continued over the whole extent of a continent.

18. **Oceans.**—The configuration of the sea, determined by the form of the lines in which it unites with the land, necessarily corresponds with the configuration of the land, and such forms are expressed by a system of geographical terms of correlative signification.

What a continent is to the land an *ocean* is to the water. This term, therefore, signifies a vast tract of water, unbroken, for the *most part,* by any tract of land.

Owing to the peculiar distribution of land and water on the globe, it follows that, strictly speaking, there is but one great ocean, between all points of which there is a continuous water communication. Nevertheless, geographers have found it convenient to divide this vast collection of water nominally into several distinct oceans, as will be explained hereafter.

19. **Seas.**—The term sea is applied to tracts of water one degree inferior in magnitude to the oceans, which are generally limited and enclosed between continents or large islands.

20. **Gulfs** are large inlets of the sea partially enclosed by land.

21. **Bays** are nearly the same as gulfs, but generally smaller. Like other geographical terms, these however are arbitrary and indefinite, some inlets called bays being greater than others called gulfs.

Gulfs and bays are the analogues of peninsulas and promontories.

22. **Straits** are narrow necks of water connecting tracts of greater extent. A strait is, therefore, the analogue of an isthmus.

A strait is often but improperly called by the plural term straits; thus the Strait of Gibraltar is frequently denominated the Straits of Gibraltar.

23. **Channels** are narrow tracts of water flowing between opposite coasts that are nearly parallel, and are much wider than straits.

24. **Roads and Roadsteads** are tracts of water sheltered by adjacent lands from violent or dangerous winds, having sufficient depth for safety, and not too great depth for anchorage. They are stations where vessels are accustomed to lie at anchor.

25. **Banks and Sandbanks** are parts of the bottom which lie so near the surface as to be attended with danger, and in places much affected by tides are often uncovered at low water.

26. **Reefs** are sunken rocks, which rise so near the surface, that the waves in passing over them are broken into foam, which thus render their presence manifest to mariners. In a calm sea, however, as there is nothing to indicate their presence, they are a great source of danger to the navigator.

27. **Soundings.**—The depth of the sea is found by a sounding-line, which is a cord of sufficient length, to the extremity of which a heavy piece of lead is attached. Upon this cord knots are made at intervals of five fathoms, the number of knots counting from the lead being indicated by visible marks. The lead is let down into the sea from the deck of the ship; the sounding-line to which it is attached being coiled round a cylinder, or reel, which turns freely on an axle. Two seamen hold up the reel by handles at the extremity of the axle, while another observes the line passing over the bulwark of the vessel. The

leaden weight sinking in the water draws with it the line, which thus unrolls itself from the reel, and this continues until the lead strikes the bottom. When that takes place the reel ceases to revolve and the line to sink, and the seaman who observes the sounding, notes the number of the knot which is nearest the surface, and thus obtains the depth, which is always expressed in fathoms.

The lead, suspended from the extremity of the sounding-line, is cup-shaped at its lower end, and grease, technically named *the arming*, is put into the cavity, so as to be capable of taking up by adhesion a portion of the shells, sand, or other substance, which is at the bottom, with which it comes into contact. This being drawn up, the navigator is informed not only of the depth, but of the quality and character of the bottom, which often serves him as a guide to his position.

In this manner surveys are made of the bottoms of all seas which are much navigated, and charts are drawn and engraved, upon each part of which is marked the number of fathoms of depth in the corresponding parts of the sea, and frequently the character of the bottom.

It happens fortunately that the general depth of the oceans and open seas is so considerable as to be attended with no danger to navigation. Such charts, therefore, as are here described are only necessary for navigation in enclosed seas and tracts of water near to coasts.

28. **Lakes** are sheets of water, of greater or less magnitude, completely surrounded by land, and having no superficial communication with the sea. They are, therefore, to the water what an island is to the land, and, like an island, the name is generally restricted to magnitudes which are not very great. A lake of great magnitude is generally called an inland sea.

Like other geographical terms, these, however, are arbitrary; some sheets of inland water called seas being less than others called lakes.

29. **Rivers** are large streams of fresh-water, formed by the rain which falls on elevated parts of the land, descending the declivities in streams, which, gradually uniting one with another, form at length a large course of water, which receives the name of a river.

30. **The Bed of a River** is a groove formed in the land, descending in a direction varying with the level of the surface, until it reaches the coast, where its water is discharged into the sea.

31. **The Banks of a River** are the land which confines its course on either side, and are distinguished as the right and left

banks, that which is to the right in descending the river, being called the right bank, and the other the left bank.

32. **Tributaries**, or affluents, are the streams which flow into a river on one side or other of its course. In the larger rivers these tributaries themselves are often considerable rivers, and receive along their course subordinate tributaries.

By reason of the common tendency of water to find the lowest level, rivers flow along the bottoms of valleys, and their winding courses, often very complicated, are determined by the varying direction of these valleys. Their tributaries run along the bottoms of smaller valleys, intersecting that of the principal river at various angles.

33. **The Valley**, along the bottom of which a great river flows, usually receives its name from that of the river, and is often of vast extent; the declivities which form its sides sometimes measuring hundreds, or even thousands, of miles.

34. **Watershed** is the name given to the declivities which thus determine the tributaries of a great river, and the whole extent of the valley is sometimes called the *basin* or hydrographic region of the river.

35. **Delta.**—A great river, in approaching its mouth, often diverges into different channels, forming angles with each other, and thus discharges itself into the sea by two or more mouths. These diverging branches are called a *delta*, from a fancied resemblance, presented by the two extreme branches and the line joining the two extreme mouths, to the Greek letter Δ, delta.

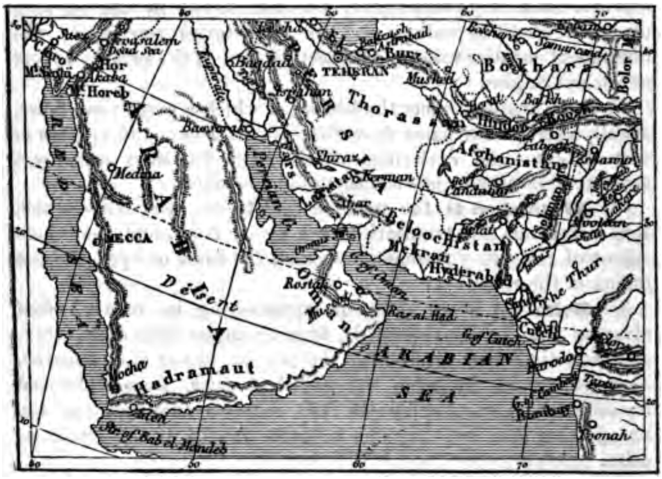
36. **Estuaries.**—The mouths of rivers are often placed in inlets of the sea, where the tide ebbs and flows, so that the waters of the sea alternately enter the mouth of the river and retire from it with the rise and fall of the tide, mixing with the water of the river, and thereby producing a constant state of agitation in the water of such an inlet. The name estuary has accordingly been given to such sheets of water, from the Latin word *æstus*, signifying the agitation of water such as that here described.

37. **Firths.**—The name firth, also written frith, is sometimes given to estuaries; this term, however, is more particularly applied in Scotland. Thus the estuary of the river Forth, which lies between Fifeshire and Edinburgh, is called the Firth of Forth.

The term firth or frith is generally assumed to be taken from the Latin word *fretum*, a strait or narrow neck of the sea. Mr. A. K. Johnson, however, considers it to be derived from the Scandinavian term *fiord*, pronounced *fiurth*, which has the same signification.

THE SURFACE OF THE EARTH.

The principal terms composing the geographical nomenclature, and expressing the forms affected by the outlines of land and waters, and the forms of relief produced by the varying elevation and depression of the surface of the land, being clearly understood, a general description of the globe we inhabit, as it is diversified by land and water, and by the undulating surface of the former, will be easily rendered intelligible.



II.—ARABIA AND PERSIA.

THE GREAT EASTERN CONTINENT.

38. **Its extent and limits.**—This vast tract has an oblong form, as already indicated; its extreme length being somewhat more than twice its extreme breadth. It is included between 20° west and 190° east longitude, and between 35° south and 75° north latitude. Nearly its whole extent lies therefore in the northern part of the eastern hemisphere. A small portion of the north-western part of Africa, including Morocco, juts into the western hemisphere, and the southern promontory of the same division of the great continent, terminating in the Cape of Good Hope, projects into the southern hemisphere.

This continuous tract of land consists, as is well known, of three unequal divisions, which, though not detached one from another *by sea, h*ave received the name of continents. The smallest of these in magnitude, but transcendently the most important in its social and political character, is EUROPE, which occupies the northwest corner of the great continent, being separated from Africa by the Mediterranean Sea, and from Asia by a low chain of mountains called the Ural, a river of the same name, the Caspian Sea, a great sheet of inland water, into which this river discharges itself, and the Black Sea.

39. **Its divisions.**—If the whole superficial extent of the great continent be supposed to consist of eight equal parts, the area of Europe will be one of these parts, that of Africa three, and that of Asia, which covers the remainder, four.

Africa is divided from Europe by the Mediterranean Sea, and from Asia by the oblong tract of water, directed N.N.W. and S.S.E., called the Red Sea. This sea is connected with the Indian Ocean, lying to the east of Africa, and the south of Asia, by a narrow neck of water, called the Strait of Bab-el-Mandeb.

40. **The Mediterranean** sea, which forms one of the most important features in the western part of the great continent, lies in a direction nearly east and west, and communicates with the Atlantic Ocean by a narrow neck of water, interposed between the southern point of the Spanish peninsula, and the north-western corner of Africa, called the Strait of Gibraltar, from the rock of that name at the point of Spain.

41. **Relief.**—The relief of the surface of the great continent is characterised by an elevated ridge, the general direction of which is parallel to its longitudinal axis, and is consequently E.N.E. and W.S.W. very nearly, but the summit of this ridge is much nearer to the southern than to the northern coast of the continent, so that it divides its area very unequally. The declivity, therefore, which slopes to the southern coast, is much more rapid and shorter than that which extends to the northern coast.

42. **Its northern belt.**—The northern division consists of a great belt of flat surface, beginning with the plains of Holland at the west, and terminating with the deserts of Siberia at the east, being only interrupted by the chain of Ural Mountains, running north and south at the confines of Europe and Asia. Except where human industry has redeemed it, and brought it under cultivation near its western extremity, the characteristic of this plain is that of marshiness and insalubrity.

43. **The southern belt.**—The more limited plain south of the ridge-summit, already mentioned, commences at the west with the great African desert of Sahara, and stretches with little interruption across Arabia, Persia, and Northern India, to the shores of Kamtschatka.

44. **Prevailing mountain-chains.**—The various mountain-

chains, the combination of which forms the main ridge of the great continent, commence with Mount Atlas and the Pyrennees at the extreme west, and are continued by the Alps and the Himalaya to the Altaic mountains at the extreme east.

45. **Outlines of Europe; their adaptation to Commerce.**—The most striking geographical feature by which Europe is distinguished from the other parts of the great continent, consists in the numerous and extensive inlets of water by which it is penetrated and intersected in all directions. No equal extent of land in any part of the globe presents a like phenomenon, and to this, as much as to its temperate climate, must undoubtedly be ascribed the immense social, commercial, and political predominance which it has acquired and maintained. By this reticulation of inland seas, gulfs, bays, and straits, navigation and commerce arrive within short distances of all its internal centres, and its vast extent of coasts is studded with cities and towns, and sheltered ports and harbours, which become so many emporiums of commerce, and centres and sources of wealth and civilisation.

46. **White Sea.**—At its extreme north, Europe is penetrated by an enclosed sheet of water of great magnitude, called the White Sea. On the west, the Baltic enters it, ramifying in different directions, throwing out north and west the gulfs of Bothnia and Finland, and sprinkled with islands and vast peninsulas, which form kingdoms of great importance, such as Denmark.

47. **Norway and Sweden** are formed into a great peninsula, separated from the continent by a broad neck of land, included between the North Sea on the west, and the head of the Gulf of Bothnia on the east.

48. **British Isles.**—Nearly opposite the mouth of the Baltic, and the north-western point of France, are placed the British Isles, separated from the coast of Holland and Belgium by the German Ocean, and from that of France by the English Channel and the Strait of Dover. These islands, combined with the subordinate ones with which they are surrounded and skirted, such as the Shetlands, the Orkneys, the Western Isles, the Isles of Man and Anglesea, the Scilly, and the Channel Islands, may be considered as forming an archipelago, the principal divisions of which are richly intersected by channels, bays, and gulfs, which have so favoured navigation, as to enable the British nation to attain and maintain that commercial and naval pre-eminence, for which she has so long been celebrated.

49. **France**, the most important and powerful of the European states, occupies the centre of Western Europe. Her territory is separated on the east from those of the German states by the Rhine,

from that of Switzerland by the chain of the Jura, from Italy by the Alps, from Africa by the Mediterranean, and from Spain by the Pyrenees. On the west it is limited by the Atlantic, and on the north, in the absence of any natural boundary, is divided from Belgium by a frontier settled by political conventions.

50. **Spain and Portugal** occupy a portion of land having the peninsular form, the neck by which it is connected with the continent extending from the Bay of Biscay to the Gulf of Lyons, and being traversed by the chain of the Pyrenees. This neck of land, so much narrower than the general width of the Spanish peninsula, is nevertheless much too wide to entitle it to the name of an isthmus.

In the geography of Europe the tract thus occupied by Spain and Portugal is usually called the **Peninsula,** without other designation.

51. **Italy.**—The southern part of Italy projects into the Mediterranean Sea in the form of an oblong tract of land, having at its southern extremity a smaller tract nearly at right angles to it; the outline of the whole presenting a striking resemblance to a boot. The Italian territory, however, occupies a wide extent of land north of the boot, enclosed on the north by the chain of the Alps. This northern part of Italy includes the territories of Venice and the Milanese, called Lombardy, at present part of the Austrian empire, and the kingdom of Sardinia. That part of the Italian territory forming the boot, being nearly surrounded by water, with the Adriatic on one side and the Mediterranean on the other, is distinguished as the Italian Peninsula.

52. **Sicily.**—Immediately at the toe of the boot, and separated from it by a narrow neck of water, celebrated in history as the Strait of Messina, is the fertile and beautiful island of Sicily, one of the most remarkable features of which is the volcano called Mount Etna.

53. **Greece** projects into the eastern end of the Mediterranean, having, like Italy and Spain, the peninsular character. These three tracts have been noticed even by ancient geographers as the Spanish, Italian, and Hellenic peninsulas.

54. **Archipelago.**—The arm of the Mediterranean which, turning to the north, intervenes between the Hellenic peninsula and the coast of Asia Minor, thickly sprinkled with islands, is the Archipelago or ancient Ægæan Sea, from which all other tracts of water of a similar character have taken their name.

55. **Dardanelles and Bosphorus.**—The Archipelago is connected with the great inland sea, called the Black Sea or the Euxine, by a narrow neck of water, consisting of two straits, between which lies a wider strip of sea. The strait which is next

the Archipelago is called the Dardanelles, the ancient Hellespont; and that which is next the Black Sea, the Bosphorus; the intermediate water being called the Sea of Marmora.

56. **The Black Sea** is nearly enclosed by land, but communicating through the Bosphorus with the Archipelago and the Mediterranean, it cannot properly be considered as a lake. Its water is, nevertheless, much less salt than that of the ocean, and it is consequently more readily frozen. Its depth near the shore varies from 24 to 220 feet, and in the middle is more than 1000 feet.

57. **Sea of Azof.**—This sea communicates with a smaller one north of it, called the Sea of Azof, by a narrow neck of water, called the Strait of Yenekali. A tract of land nearly surrounded by the waters of the Black Sea and the Sea of Azof, and connected with the continent by a narrow neck of land, is called the Crimea; the connecting neck being called the Isthmus of Perikop. This peninsula has been celebrated for the fortress of Sebastopol erected by Russia near its southern extremity, and destroyed in 1855 by the allied armies of France and England.

58. **The Caspian.**—Near the southern confines of Europe and Asia is the largest lake in the world, called the Caspian Sea. Its water is salt, but much less so than the ocean, and it is shallow, even at its centre, the depth not exceeding 300 feet. That it can have no immediate and uninterrupted subterranean communication with the Black Sea, which is near it, is proved by the fact that the level of its surface is 82 feet below that of the latter sea.

59. **Africa** is an immense triangular-shaped tract of land, the base of which is presented towards the north, and the point to the south. Its coast is everywhere nearly uniform, and entirely destitute of those indentations for which Europe is so remarkable. It projects southwards into the great ocean, which it divides into two regions, of which the western is called the Atlantic, and the eastern the Indian Ocean. As has been already stated, Africa is separated from Asia by the Red Sea, except at the point where they are connected by the narrow isthmus of Suez.

This division of the great continent is, beyond all comparison, the most uncivilised and desert portion of the globe. It includes a vast range of country, extending from the northern to the southern tropic, and lying, therefore, altogether in the torrid zone. By reason of the great extent of desert of which it consists, the insalubrity of its climate, and the barbarous character of its inhabitants, it is little known to Europeans.

60. **Its Climatological Zones.**—It may be considered as consisting of a succession of zones, separated by parallels of latitude, having different physical characters.

61. **The Tell and Sahara.**—The northern zone, included between the ridge of Mount Atlas and the Mediterranean, is a band of fertile country, generally called the *Tell*, probably from the Latin word *tellus*, the earth. South of this is a vast band, running east and west, about 1800 miles broad, comprising Sahara or the great desert. This extensive surface consists of tracts of sandy and stony soil, rarely producing vegetation, and, when it does, of the most scanty description, with the exception of certain spots appearing here and there in this ocean of desolation, like islands of fertility. These are called Oases, and depend for their productiveness on local springs.

62. **Valley of the Nile.**—On the west this desert not only descends to the verge of the ocean, but is continued with the same character for many miles beneath its surface and beyond the coast. On the east, it descends by a series of sterile terraces to the valley of the Nile, where the soil suddenly acquires a high degree of fertility, which character it retains throughout the whole extent of country between the Nile and the Red Sea. The entire valley of the Nile, from the skirt of the Desert to the Delta, and from the right bank of the river to the Red Sea, has been celebrated in ancient history for its general fertility, a character, nevertheless, which is not altogether without exception, an example of which is presented in the tract over which the route between Cairo and Suez is conducted.

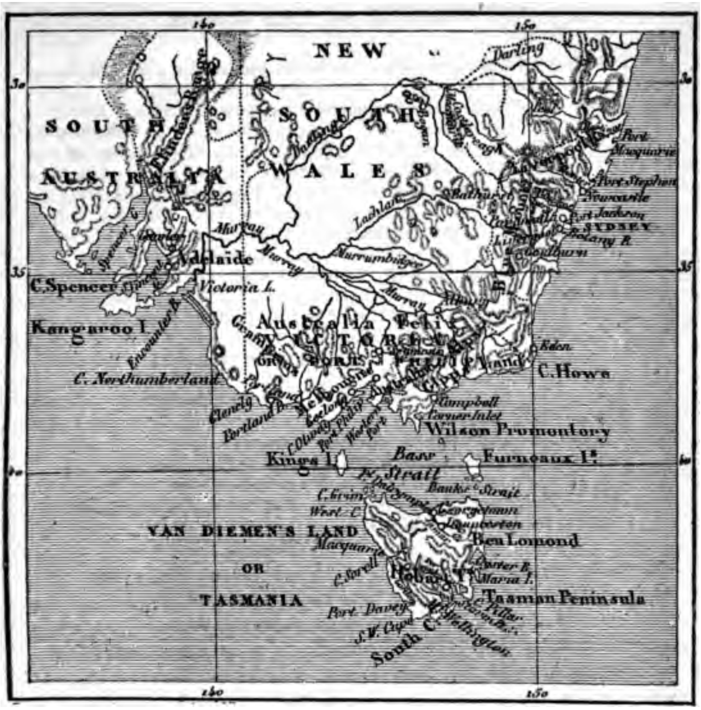
63. **The central Belt** of Africa, immediately south of the great desert, has quite a different character, being both fertile and populous.

64. **The fourth zone,** lying south of this, is almost unknown, except on its seaboard. It is supposed to consist of an extensive and elevated table-land, with lofty mountain-ranges rising out of it, from which character it is distinguished in geography as High Africa.

65. **The southern zone** of the great African peninsula consists of a triangular area, the vertex of which projects into the Southern Ocean, and is terminated by the celebrated Cape of Good Hope. This part is diversified by hill and valley, and is naturally fertile, supplying extensive pasturages. The native tribes which inhabit it are the Hottentots and Caffres. The English colony, originally Dutch, has been generally confined to the southernmost part of the angle, but has a constant tendency to push their territory further north, thereby coming into contact, and frequently into conflict, with the natives.

66. **The coasts.**—It has been already observed that the coasts of Africa are singularly destitute of all projections and indentations, and, consequently, ill-adapted for commerce. For the

same reason, there is a remarkable absence of those numerous islands which enrich all coasts deeply indented, which considered in their physical character are in fact parts of the mainland, separated from it by valleys so deep as to allow the sea to flow through them. Madagascar, on the east coast, is the only African island. There are a few islands of much less magnitude, called the Comano Islands, between Madagascar and the coast. Most of the other islands which appear in the Indian Ocean are too distant to be regarded as mere appendages of Africa.



III.—AUSTRALASIA.

THE SURFACE OF THE EARTH,

OR FIRST NOTIONS OF GEOGRAPHY.

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CHAPTER II.

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67. **Asia,** constituting in geographical extent fully half the great continent, and occupied by a population numbering half the total amount of the human race, is in many respects an interesting quarter of the globe. It is in immediate geographical continuity with Europe, separated from Egypt only by the narrow strip of water called the Red Sea, and connected with it by the isthmus of Suez, and separated on the east from the American continent by the narrow neck of water called Behring Straits. Its eastern coast is fringed with innumerable islands, and indented by large bays and gulfs; and its southern points are in a certain sense connected with the new continent of Australia by the archipelago which intervenes between the Indian and Pacific Oceans, of which the most considerable islands are Sumatra, Borneo, Pappua, and Java. The equator traverses the middle of this archipelago, the whole extent of which is included between 20° of north and 10° of south latitude.

68. **Its plateaux.**—The mainland of Asia consists of two extensive plateaux, each of which is limited and intersected by mountain-chains, from which the surface falls by a succession of slopes and terraces to the level of the lowlands.

69. **The eastern plateau,** which is the most elevated, including Thibet and the desert of Gobi or Shamo, has an elevation varying from 4000 to 15000 feet above the level of the sea.

This great tableland has for its southern limit the Himalaya *chain,* for its northern the Altai, and the chain called Thian. On the west it is limited by the Bollortagh, and on the east by a chain running directly north from Pekin called the Khingan mountains.

70. **Its physical character.**—The physical character of this vast plateau may be in some degree comprehended, when it is stated that it consists of three-fourths of a million of square miles of surface, having a general elevation greater than that of the most lofty mountain-ranges of Europe.

This plateau descends towards the north by gentle slopes, so as to convert the extensive zone of surface along the northern coast into a vast plain, the general elevation of which above the surface of the sea does not exceed a few hundred feet.

On the south and south-east sides, the great plateau advancing comparatively close to the coast, the descent is much more rapid.

71. **The western tableland** embraces the tract between the Caspian Sea and the Persian Gulf on the north and south, and the river Indus on the east. It does not exceed 4000 feet in elevation, and is generally less. This tract, called the tableland of Iran, the ancient Persia, is now divided into Cabul on the east, and Persia on the west. Stretching in the direction of the north-west to Asia Minor, it slopes gradually down to the archipelago.

72. **British India: Dekkan plateau.**—One of the geographical features of this division of the great continent is the triangular projection which juts down into the Indian Ocean, and constitutes the chief part of the territory of British India. This also consists of a plateau, of moderate elevation, called the *tableland of Dekkan.* Between this, which covers the whole extent of the peninsula and the Himalaya mountains which run east and west, is a plain of low elevation, called the plain of Hindoostan, forming the valley along which the Ganges, with its tributaries, flows from west to east, forming its delta, and discharging itself into the Bay of Bengal, at the northern extremity of that gulf near Calcutta. The western portion of the same plain slopes towards the Arabian Sea, and is the valley similarly drained by the Indus and its tributaries.

73. **Australia,** formerly called New Holland, is an insular mass, whose extent and importance are such that it has ceased to be called an island, and is now generally ranked as a continent. It is placed south of the line between latitudes 15° and 40°. Near it are several other islands of less magnitude, the principal of which is New Zealand. South of it is a smaller island, formerly called Van Diemen's Land, and now denominated Tasmania.

74. **Australasia.**—The group consisting of Australia, Tasmania, New Zealand, and the smaller islands near them, are

called by modern geographers Australasia, being the most considerable tracts of land in the southern latitudes. The various islands sprinkled in countless numbers over the Pacific Ocean, comprising Australasia itself, have received the general name of Oceania.

75. **Polynesia.**—Those which lie between the Indian Archipelago and the western coast of America, taken collectively, have been called *Polynesia.*

76. **British Colony; its territory and physical features.**—From the circumstance of the recent gold discoveries, and the consequent emigration from the United Kingdom to Australia, this colony has acquired a greater interest than any which its mere geographical pretensions could claim for it. It may therefore be desirable here to notice its physical character and conditions.

Notwithstanding the immense immigration which has taken place, and the excitement attending the mineral researches, of which it has become the theatre, the surface of this great island has been but very imperfectly explored. One of the most remarkable and geographical characters it presents is the complete absence of large navigable rivers, and the uniform outline of its coast, which has no indentations forming bays, gulfs, or other inlets. It is surrounded by a chain of mountains, the summit-ridge of which is from 30 to 40 miles from the shore. The chain running along the eastern coast, which is best known, is called the Australian Alps at the extreme south, the Blue Mountains near Sidney, and the Liverpool chain towards the north. From the slopes of these mountains a few small rivers descend, which are so inconsiderable as to be nearly dry in summer. The interior consists of a series of low plains, which include good pasturages, and large tracts covered with sand and shells, which have an appearance such as would be presented by a surface from which the sea had recently retired. Some considerable streams have been seen in the interior, but whether they flow into an inland sea like those which run into the great Asiatic lake, or are absorbed by the sands, has not been ascertained.

One of the most curious physical characters connected with this island is the existence on its north-eastern coast, at a distance of from 20 to 70 miles, of the longest coral reef in the world, measuring about 1200 miles in length, and rising out of the bosom of a sea said to be fathomless. The breadth of this reef varies from a few hundred yards to several miles.

77. **Its climate.**—When it is remembered that the extreme latitudes of Australia are 15° and 40°, it may be expected that its climate must be mild and salubrious. With a drier atmosphere *it has all* the thermometric characters of Southern Italy. The

vegetation seems to be maintained by the deposition of dew, for it often happens that intervals of several years elapse without rain. When rain does occur, however, it is periodic, and prevails through three months.

78. **Vegetable productions.**—The natural vegetable productions are neither considerable nor useful; there is no species of edible fruit. The trees composing the woods appear to be of one uniform family, the foliage being scanty and almost shadowless. On the other hand, transplanted vegetation is easily naturalised. Districts are found adapted to the cultivation of all sorts of grain; but, for the present, the most advantageous employment of the soil is for pasturage.

79. **The indigenous animals** are few, being mostly of the family of marsupia, such as the opossum and kangaroo. The most remarkable and anomalous of these animals is one called the ornithorhynchus, which is a sort of connecting link between birds and quadrupeds, having the bill and feet of a duck, and the body and fur of a mole.

80. **Minerals—Gold**—It is well known that gold in large quantities is found in this region. It may be added, however, that coal and iron also exist there in inexhaustible quantities, as well as marble, lead, and copper.

81. **Aboriginal Tribes.**—The native tribes, which appear to prevail in but limited numbers, are in the lowest state to which nature can sink. They are generally nomadic, but sometimes build rude villages, and subsist by fishing on the coast.

So utterly degraded is their condition, moral and physical, that many tribes are unprovided with clothing, practise cannibalism, and are wholly destitute of social and religious ideas.

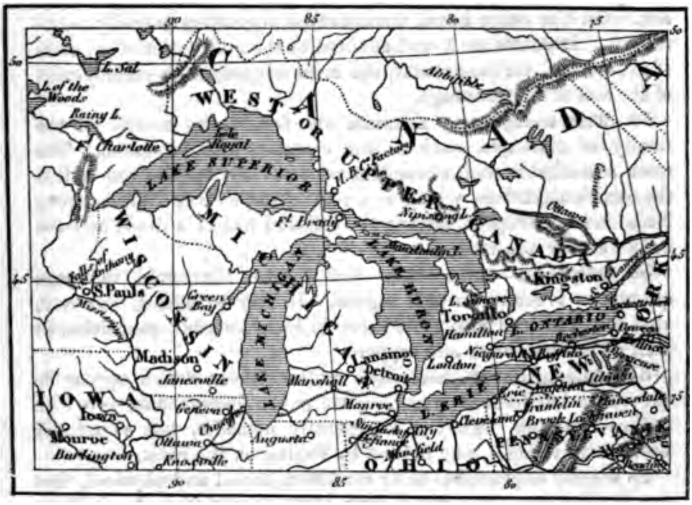
THE WESTERN, OR NEW CONTINENT.

82. **Its extent and form.**—Like the great eastern continent, the western is an oblong tract of land, the length of which intersects the parallels of latitude obliquely, being directed first from the S. S. E. to N. N. W. and then turning eastward in approaching the pole. It extends from 50° S. lat. to the utmost limit of polar discovery.

83. **Divisions—South America.**—This continent consists of two peninsulas, connected by a narrow tract of considerable length. The southern peninsula resembles Africa in its general outline, having a triangular form, with its base towards the north, and its vertex to the south. It also resembles the African continent in having coasts but little indented by bays or gulfs,

but differs from it in being intersected by large and extensive rivers.

84. **Central America** is the tract of land uniting South America with the northern peninsula. Its southern part being not more than 30 miles wide, is denominated the isthmus of Darien or Panama, a town of the latter name being on its western coast.



IV.—UNITED STATES—CANADA.

85. **North America**, like Europe, is indented with numerous bays, and its northern division has the largest collections of fresh water in the world, consisting of five extensive lakes,—called Superior, Michigan, Huron, Erie, and Ontario, which communicate with each other, and discharge their water through the River St. Lawrence into the gulf of that name.

86. **Its extent and limits.**—North America is separated from Asia by Behring Strait on the west, and from the large island of Greenland by Baffin's Bay and Davis's Strait on the north and east.

A sort of northern archipelago intervenes between this continent and Greenland, into which numerous promontories project, and the waters of which are variously denominated, the largest of these inlets being Hudson's Bay.

87. **Its political divisions.**—In political geography North

America consists of several divisions, the central part being the United States, the north-eastern British America, the north-western angle near Behring Strait, Russian America, and the part forming the southern point, Mexico.

88. **Gulf of Mexico and Caribbean Sea.**—The large inlet of the ocean enclosed between the northern coast of South America, the southern coast of North America, and the eastern coast of Mexico and Central America, consists of the Gulf of Mexico and the Caribbean Sea, its eastern part, sprinkled with the West Indian islands, forming an archipelago.

89. **Relation between the coasts of Old and New Continent.**—It has been observed by Humboldt, that on comparing the eastern coast of South America with the western coast of Africa, the same correspondence is observed between them as is usually seen in the opposite sides of a valley or ravine; from which he argues that the bottom of the Atlantic, which flows between these continents, ought to be regarded as an extensive valley, the sides of which, rising to an elevation above the level of the water which fills it, form the coasts of the two continents. Thus the concavity on the African coast, called the Gulf of Guinea, has a corresponding convexity on the South American coast forming the territory of Brazil, and the convexity at the north-western corner of Africa, of which the coast of Morocco forms a part, corresponds with the opposite concavity formed by the Caribbean Sea and the Gulf of Mexico. So that if the two continents were moved towards each other, and brought into contact, their coasts would fit into each other, like the dove-tailed edges of carpentry. The Atlantic, following the course of this submarine valley, entering between the Cape of Good Hope and Cape Horn, flows first in a northerly direction, a little towards the east, next, after passing the Gulf of Guinea, in a north-westerly direction, and finally, after passing the north-western coast of America, in a north-easterly direction.

90. **The relief** of the western continent is characterised by a continuous ridge of considerable elevation, which traverses it longitudinally from its northern to its southern limit, lying much nearer to the western than to the eastern coast.

91. **Chippewayan and Rocky Mountains.**—The part of this ridge or mountain-chain which traverses North America, commencing at the Frozen Ocean, is called in its northern division the Chippewayan range, and in its southern division by the better known name of the Rocky Mountains.

92. **Cordilleras and Andes.**—After passing along Central America, this ridge takes the name of the Cordilleras and Andes, and rising to much greater heights, and throwing up vast peaks

which are frequently volcanic, it is continued in a direction parallel to the western coast of the continent, until it terminates in the Tierra del Fuego, the southern point of which is called Cape Horn.

93. **Andes of Patagonia and Chili.**—Between this point and Chili, returning northwards, the slopes of the Andes descend to the waters of the Pacific, the coast being lined with numerous islands and indented with arms of the sea, an outline which indicates the continuation of the mountain range below the waters of the ocean; the capes, promontories, and islands being merely the ridges and summits of the spurs and peaks of the main range, whose bases are established at the bottom of the ocean. Proceeding northward, the general direction of the chain takes a more inland course, leaving between its base and the sea a long and flat tract of land, whose coast is no longer broken by the indentations just described, is completely destitute of islands, and forms no shelter for navigators.

94. **Andes of Bolivia and Peru.**—Still proceeding northward and approaching the Peruvian territory, the general elevation of the Andes rapidly increases, and their summits rise to vast elevations above the snow-line; among these is the Nevado Aconcagua, having an elevation of 24000 feet, and being the most lofty point of the western continent. This peak was originally volcanic, but within historic record it has not been active.

About latitude 24° south, the chain takes the name of the Peruvian Andes, and here it is at a considerable distance from the western coast, from which it is separated by a sandy desert.

95. **Cordilleras.**—North of 21° lat. south, the chain of the Andes diverges into two or three separate ridges, called Cordilleras, which are connected at different points by their common spurs issuing transversely to their directions, so as to form a net-work enclosing numerous valleys, the bottoms of which are elevated to a considerable height above the level of the sea, forming in many cases plateaux and tablelands of great extent, the most remarkable of which is that of Desaguadero, which measures 400 miles in length, with a breadth varying from 30 to 60, and a general elevation of nearly 13000 feet above the level of the sea. Vast peaks are thrown up from the borders of this immense plateau to the height of more than 8000 feet above the surface, rising far above the snow-line.

96. **Potosi.**—Upon this extensive tableland, whose area is three times that of Switzerland, stands Potosi, the highest city in the world, at an elevation of 13330 feet above the level of the sea, with a population of 30000. This city is built on the

northern declivity of a mountain called Cerro de Potosi, which is rich in mineral veins, and especially in silver.

97. **Pampas of Patagonia and Buenos Ayres.**—Since, as has been explained, this great chain runs close to the western coast, it may be expected that a vast tract of plains, or lower lands, must extend from the foot of its eastern declivity to the eastern coast of the continent. This tract in South America is covered with the deserts and pampas, as they are called, of Patagonia and Buenos Ayres, the surface of which is sandy and marshy, or saline, producing nothing but a scanty pasture and stunted trees.

98. **Selvas of Amazon.**—Another portion, consisting of the valley of the great River Amazon, called Selvas, consists of a space of more than two millions of square miles, a part of which is covered with natural forests, and the remainder with grassy pampas.

99. **Llanos of Orinoco.**—The valley of the Orinoco, another division, is characterised by vast flat lands, called Llanos, covered with long grass, interspersed here and there with palm trees, used by the traveller in these inhospitable regions as landmarks.

100. **Alleghanies.**—Extensive lowlands stretch in like manner over North America, between the chain of the Rocky Mountains and the eastern coast. This division of the continent is also intersected in a direction parallel to the Rocky Mountains, and nearer to the Atlantic by a chain of much lower hills called the Alleghanies, which, like the former, extend from the Gulf of Mexico to the Arctic Ocean, enclosing an area of more than 3,000000 of square miles.

101. **Eastern Plain of North America.**—Between the chain of the Alleghanies and the Atlantic coast is another plain parallel to the former, of nearly equal length from north to south, but of less width. The eastern coast is indented and fringed with numerous bays and creeks, which favour commerce and navigation.

102. **Great Valley of the Mississippi.**—The extensive valley lying between the chain of the Alleghanies and the Rocky Mountains is drained by the Mississippi, the largest and most important river in the world, next to the Amazons, which, nevertheless, it exceeds in length, though inferior to it in the extent and number of its tributaries.

103. **The Prairies.**—Among the features which characterise the land in the western continent, and more especially in its northern part, the Prairies demand especial notice. These are vast plains, generally covered by deep herbage, and which form a level so dead and uniform, that it is impossible to resist the

impression that they must have been once the bottoms of large sheets of water, since nothing but sedimentary deposition could produce a level so uniform. The extent of many of these plains is so great, that in traversing them points may be attained from which all the surrounding country will cease to be visible, so that the prairie presents to the observer a circular horizon, like that witnessed at sea from the deck of a ship.

As there are, in general, no roads or paths traversing these vast plains, the traveller who ventures across them can only guide his steps by a compass, or by the stars.

OUTLINES OF THE LAND.

104. The prevalence of the peninsular form with the pointing southwards is one of the most remarkable features in the configuration of the land. The angular point is also generally succeeded or surrounded by one, or several islands; and where such islands are not apparent, the tendency towards their formation is discoverable by the soundings, which prove the existence of shoals in the places where such islands would otherwise be apparent. A general view of the map of the world will strikingly illustrate these observations.

105. **The South American Peninsula** is an example of such a form upon a grand scale. Like all the other forms of this class, it is a triangle, having its base presented towards the north, and its vertex jutting into the Southern Ocean, where it terminates in the point called Cape Horn.

Its apex is broken by the ocean into a multitude of islands, the largest of which, separated from the main-land by the Straits of Magellan, is called the Tierra del Fuego, or land of fire, from several volcanic peaks which rise from it to the altitude of 4000 feet. The southernmost island of the Fuegian archipelago terminates in the headland, or promontory, so well known as Cape Horn.

106. **The North American Peninsula** has a like form, its southern point being Mexico; but instead of terminating in the ocean, it is united with the South American peninsula by a tract of land called Central America, which, taken as a whole, may be regarded as an isthmus, although geographers have, in this case, limited that name to its southernmost and narrowest part, called the Isthmus of Panamà.

107. **The West Indian Archipelago** stands in the same relation to the North American peninsula as the Fuegian archipelago to the southern peninsula. This group of islands, celebrated as being the theatre of the great discovery of Columbus, is included

in the tract of water enclosed between the northern coast of South, and the southern coast of North, America. When Columbus undertook his voyage, his purpose was to sail to India round the western hemisphere of the globe, and when he arrived at the island of St. Salvador, one of the Bahama group, he imagined that he was on the coast of India; and hence this, and the other islands of the archipelago subsequently discovered, came to be called the West Indies: they are, however, more commonly denominated by French and foreign geographers the Antilles.

The extensive tract of sea enclosed by the coasts of North and South America, and the chain of West Indian Islands, is denominated the Gulf of Mexico, and the Caribbean Sea; the former being included by the southern coast of North America, and the northern of Central America, and the latter by the northern coast of South America, the West Indian Islands, and the eastern coast of Central America.

108. **The Peninsula of Florida** presents another example of the like form. It is the southernmost point of North America, jutting into the ocean between the Atlantic and the Gulf of Mexico, and terminating in Cape Sable, directly north of the well-known harbour and city called Havannah, in the island of Cuba.

109. **Lower California** has the same peninsular form, directed southwards. It lies on the western coast of Mexico, from which it is separated by an inlet of the Pacific, called the Gulf of California. It is terminated at its southern point in a headland called Cape St. Lucas.

110. **Greenland**, in the extreme north, presents an example of similar formation, being formed into an acute angle, jutting out into the Atlantic towards the south.

111. **Africa**, in the Old World, is a stupendous example of the same peninsular outline. Like South America it is triangular, the base being presented to the north, and the vertex to the south. There are no islands below its vertex, but the tendency to the formation of one is indicated by the shoal called the Lagullas Bank, well known to mariners.

112. **Australia** has a similar form, terminating with the island now called Tasmania, and formerly known as Van Diemen's Land.

113. **New Zealand**, on a much smaller scale, presents a like example, terminating with an island called New Leinster.

114. It is very remarkable that this tendency to the peninsular form with a southern vertex, not only prevails in the continents, but is discoverable equally in the more minute outlines of the land which determines the shores of gulfs, bays, and inland seas.

115. **The Spanish Peninsula**, including Portugal, is an ex-

ample of the same prevailing form, its southern apex being marked by the celebrated rock of Gibraltar, separated from the northern coast of Africa by the narrow neck of water called the Strait of Gibraltar.

116. **The Italian Peninsula** juts southwards into the Mediterranean, with the islands of Sicily and Malta, and the small archipelago formed by the Lipari Islands, at its southernmost point.

117. **The Hellenic Peninsula** is a like example, terminated by the Morea, and surrounded near its southernmost point by the Ionian Islands.

118. **The Crimea**, in the Black Sea, is a peninsula of like form and position, terminating with a southern vertex near Sebastopol.

119. **The Scandinavian Peninsula** consists of Norway and Sweden, and enclosed between the Northern Atlantic on the west, and the Baltic and the Gulf of Bothnia on the east, presents, like the others, an apex to the south, and Zealand, and other smaller islands, lie off its southern point.

120. **European Peninsula.**—Humboldt observes that Europe itself may be regarded as a great peninsula projecting from Asia, and enclosed between the Mediterranean and Black Sea on one side, and the Baltic and Arctic Ocean on the other.

121. **The Indian Peninsula** juts into the ocean southwards, having, like the others, a triangular form, and the island Ceylon off its southern apex.

122. **Further India.**—The tract of land called Further India, lying to the south of China, and including Cochin China, Siam, and Burmah, is another example of like form, terminating in the Malayan promontory with Singapore at its apex, and the Indian archipelago around its point.

123. **Hemisphere of most Land.**—There is a certain hemisphere of the globe within which nearly the whole of the land is included, the middle point of which is at the south coast of England. If an observer were elevated directly above this point, so as to obtain a bird's-eye view of the earth, he would see the whole of Europe, Asia and Africa, North America, and the chief part of South America, all comprised within the visible hemisphere: the only parts of the land which would be included within the hemisphere beyond his view would be the southern point of South America, Australia, and the islands of the Indian Archipelago.

In Map 8, we have given these two hemispheres, having reproduced them from the Physical School Atlas of Alexander Keith Johnston, a work which we strongly recommend to students to aid them in comprehending this tract.

RIVERS.

124. **Formation of Rivers.**—The origin of all rivers is the evaporation of the ocean. The surface of the oceans and seas has an extent, as has been already explained, equal to nearly three-fourths of the whole surface of the globe. This extensive mass of water is subject to an incessant process of evaporation. In this process, the pure water is separated from the salt and other solid matter which it holds in solution. The vapour, therefore, which ascends into and mixes with the atmosphere, is that of pure fresh water. Being lighter bulk for bulk than the air, it rises into the higher regions, where it is transported in different directions by atmospheric currents. By the operation of temperature and electricity, it is converted into clouds, which, attracted towards the most elevated points of the land, collect in dense masses around the ridges and summits of the mountains, where, being condensed and reconverted into water, and sometimes congealed, it is precipitated in the form of rain or snow. From these heights it descends by the common principle of gravitation, either along the surface of the declivities, or through the fissures and interstices of the soil, finding its way to the lower levels; and, following these in their devious and winding course, it at length returns to the sea, with which it mingles, to be again evaporated and sent once more through the same series of physical changes.

125. **Effect of a single ridge.**—When a tract of country, bounded on either side by the sea, is traversed by an elevated ridge or chain of mountains, the rain and snow deposited upon them descends in streams along their slopes at either side, forming at first rivulets, which, coalescing, swell into larger streams, and acquire the character of rivers. These, following the declivities and winding through the valleys, find their way on the one side or the other to the sea. In this case, the general direction of the rivers will be at right angles to the ridge which traverses the country. The rapidity of their streams will be proportionate to the steepness of the declivity, and their length to the distances of the prevailing ridge from one or other coast.

126. **Example in the Eastern Continent.**—An example of the play of this principle is presented in the great eastern continent, where, as has already been explained, the mountain-chains running from west to east are much nearer to the southern than to the northern coast. The rivers, therefore, which flow towards the south, are generally shorter and more rapid, while those which flow towards the north, passing over exten-

sive tablelands and plains having little declivity, are comparatively long and sluggish.

127. **Example in South America.**—South America presents a similar example. The chain of the Andes traversing the country north and south, and much nearer to the western than the eastern coast, gives a similar character to the rivers, those which flow to the west being short and rapid, and those which flow to the east being longer and slower.

In the northern part of South America, the principal mountain chain, diverging into several distinct ridges of the Cordilleras, produces a complicated system of ravines and valleys, which divert the course of the waters in various directions, so that many of the rivers flow northwards and north-westwards into the Caribbean Sea.

128. **Effect of Parallel ridges.**—When a tract of country is traversed by two ridges in nearly parallel directions, their declivities, which look towards each other, form a valley of greater or less width. The rain precipitated upon these slopes, collecting in streams, descends from either side to the lowest point of the valley where they coalesce, and settling into a bed or channel, flow along the lowest level of the valley, forming a river whose course is parallel to the general direction of the bounding ridges, and which continues its course until it discharges its waters into the sea.

In ascending a river, it is found, as may be expected, that the quantity of water which flows in it becomes less and less as the distance from its mouth increases. Since the total collection of water must be proportionate to the number and magnitude of the tributaries above the point of observation, the higher that point is, the less will the number of such tributaries be, and consequently the less the quantity of water in the main stream.

129. **Chief tributaries considerable rivers.**—In the case of all the great rivers, the principal tributaries themselves are rivers of considerable magnitude and importance, and some which have been classed as tributaries might with greater propriety have been considered as the main stream.

130. **Example of Missouri.**—Thus for example the Mississippi receives as tributaries, streams so important as the Red River, the Arkansas, the Ohio, the Missouri, and the Illinois. Now the Missouri is itself a river of much greater length, width, and depth than that which above their confluence has been denominated the Upper Mississippi, and if, of two confluent streams, the greater be entitled to be regarded as the continuation of the main stream, the river which is now called the Missouri ought to be denominated the Upper Mississippi.

131. It must not be inferred from what has been here stated that the valley of every river is formed by slopes, having declivities obvious to the eye, or limited by chains of mountains of conspicuous elevation. Most commonly it is quite otherwise, the declivities of the valley being so gentle as to be almost imperceptible, and the summits of the ridges, which limit it, having no elevation which entitles them to the name of mountains.

132. **Portage.**—Where the navigation of a river is impeded by waterfalls, rapids, shallows or other natural obstructions, the space over which goods, and sometimes canoes or boats have to be carried, to meet the navigable part of the stream again, is called a *portage*.

133. **Examples of rivers of North America.**—This division of the western continent being traversed by two ridges, the Rocky Mountains and the Alleghanies, whose general directions are nearly parallel, is divided into three zones, running north and south, the centre and broadest of which is included between the two ridges, the eastern zone sloping down from the Alleghanies to the Atlantic, and the western from the Rocky Mountains to the Pacific.

134. **Eastern rivers.**—The disposition of the general relief of the continent, shown by a section of it, running east and west, determines three different directions for the rivers. Those which are formed of the drainage of the eastern slopes of the Alleghanies, flow eastward into the Atlantic, and the distance of the ridge of the Alleghanies from the Atlantic coast not being great, and the surface of the intervening zone being nearly plane, the lengths of the rivers are inconsiderable, and their streams not rapid.

135. **Western rivers.**—In the same manner the drainage of the western slope of the Rocky Mountains forms a series of rivers which flowing westward fall into the Pacific.

136. **The Mississippi and its tributaries.**—The great extent of the valley included between the ridges of the Alleghanies and the Rocky Mountains, and its great capacity for cultivation, confer upon it an importance which is immensely augmented by the great length through which the rivers which traverse it, are navigable.

137. The drainage of the western slopes of the Alleghanies, and that of the eastern slopes of the Rocky Mountains, form two systems of rivers, the one flowing from west to east, and the other from east to west, and meeting in a common bed in the centre of the valley. They thus form a main stream traversing the valley from north to south, the magnitude of which increases as it descends southwards, in proportion to the number and magnitude of the streams which flow into it from the one side or the other. This central stream is the Mississippi, which gives its name

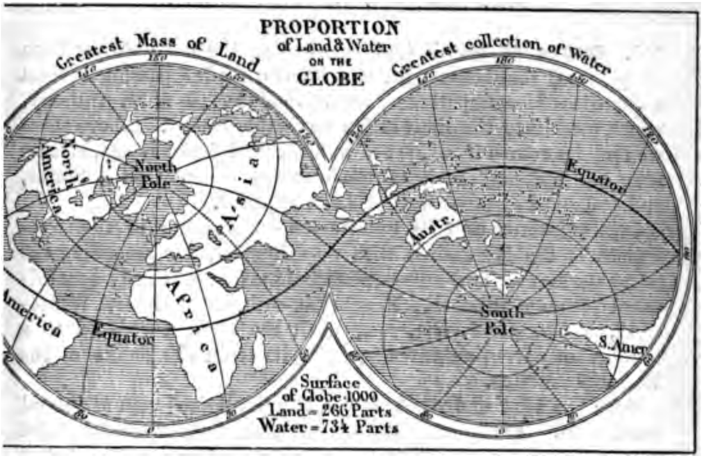
to the entire valley, extending from the Gulf of Mexico, into which its waters fall, to the great northern lakes.

138. **Red River—Arkansas—Ohio.**—New Orleans, which is the port of the Mississippi, is built at the confluence of the arms of its Delta, about one hundred miles above its mouth. Ascending the river from this point, we encounter successively its vast tributaries, the first of which is called the Red River, which flows into it from the slope of the Rocky Mountains upon its right bank. Proceeding upwards, the next is the Arkansas, on the same side, which itself receives at various points of its course subordinate affluents, among which the principal are the Canadian, the Red Fork, the Salt Fork, &c. A little higher, we come to the Ohio, flowing from the east, after having traversed a vast extent of the great valley, and receiving several large tributaries, such as the Cumberland, the Tennessee, the Wabash, &c. The Ohio carries the chief part of the commerce of the states of Tennessee, Kentucky, Virginia, Ohio, Indiana, Illinois, and the western part of Pennsylvania. It washes Pittsburgh, Cincinnati, and Louisville, while its tributaries reach the principal towns of the interior of the adjacent states. It is navigated by steam-boats of the largest class as high as Pittsburgh.

139. **St. Louis.**—Returning to the confluence of the Ohio and the Mississippi, and continuing to ascend the latter river, we arrive at St. Louis, a city of the first importance, and likely one day to become the great capital of the valley of the Mississippi and the western division of the States, with New Orleans for its port. Already we see ranged along its quays hundreds of steam-boats of immense tonnage, which ply incessantly between it and New Orleans, carrying down the stream the produce of the interior, and up, innumerable articles of importation.

140. **Illinois.**—Immediately above St. Louis we arrive at a point marked by the confluence of three streams, one flowing from the north-east, one from the north, and the other from the north-west, the last being the most considerable. The first is the Illinois river; the second, though less considerable than the third, is taken by geographers as the continuance of the main stream of the Mississippi; and the third and greatest is the Missouri, regarded as a tributary of Mississippi.

The Illinois river ascends the state of that name in a north-easterly direction, and is navigable for a considerable distance to a point where it is connected by a canal with Lake Michigan at Chicago. By this means a continuous water-communication is established between New Orleans and the northern lakes, and by those lakes with the St. Lawrence.



VIII.—LAND AND WATER.

THE SURFACE OF THE EARTH,

OR FIRST NOTIONS OF GEOGRAPHY.

◆

CHAPTER III.

141. Source of Mississippi.—142. Missouri and its tributaries.—143. The Amazons.—144. Its tributaries.—145. The Orinoco.—146. The Rio de la Plata.—147. The river system of Europe.—148. General plan of the rivers of the world. CLIMATE.—149. Determines the animal and vegetable kingdoms.—150. Its dependence on latitude.—151. Explained by the varying positions of the earth.—152. Spring equinox.—153. Sun vertical at equator.—154. Oblique at all other points.—155. Its thermal influence in different latitudes.—156. Position of the earth on 21st June.—157. Days longer than nights in northern hemisphere.—158. Temperature depends on sun's altitude and length of day.—159. Thermal influence greatest on 21st June in northern hemisphere.—160. Position of the earth at autumnal equinox.—161. Why the longest day is not the hottest.—162. Why the summer is warmer than the spring.—163. The Dog-days.—164. Like phenomena in the southern hemisphere.—165. Position of the earth on 21st December.—166. Winter season explained.—167. Why the shortest day is not the coldest.—168. The Tropics.—169. The sun can only be vertical within them.—170. Illustration of the varying position of the earth in the successive months.—171. The arctic polar circles and the frigid zones.—172. Diurnal and nocturnal phenomena which characterise them.—173. The torrid zone.—174. Sun vertical twice a year in the torrid zone.—175. Temperate zone.

141. **Source of Mississippi.**—Ascending the main stream from its point of confluence with the Missouri, after passing several tributaries of less importance, we arrive at the falls of St. Anthony, which constitute the limit of its navigable course. Above these we find its source in a sheet of water, called Lake Istaca, situate near the northern limit of the territory of the United States, and at a short distance west of Lake Superior.

142. **Missouri and its tributaries.**—Returning to the confluence of the Mississippi with the Missouri, and ascending the latter stream, we find innumerable tributaries, variously denominated Smoky-hill-fork, Republican-fork, Platt-river, White-river, Yellow-stone-river, &c., until the stream, reduced to a number of diverging threads, loses itself in the flanks of the Rocky Mountains.

Such is a brief and rapid view of this prodigious vein of inland navigation. As shown in our general plan of the rivers, the total length of the Mississippi and its chief tributary is estimated at 4500 miles.

143. **The Amazons.**—Among the rivers of Southern America, which flow from the western declivities of the chain of the Andes, by far the most important is the Amazons, which, considered merely in its geographical character, ranks as the greatest of rivers. The total length from the mouth to the source of any one of its thousand tributaries, is less than the length of the Mississippi similarly measured, but numerous and large as the tributaries of the latter are, those of the Amazons are still greater in number, width, and depth.

This immense stream, and its countless affluents, drain a vast plain lying between the tableland of Brazil, on the south, and the chain of mountains rising from a similar tableland of less extent, on the north, called the tableland of Paramo. It receives tributaries accordingly from an extensive series of declivities completely surrounding it, from those of Brazil on the south, from the Andes of Peru on the south-west, from the Andes of Quito on the north-west, and from those of the mountain-chains of Paramo on the north.

The plain and surrounding declivities drained by this immense river system, is little less in extent than 3,000000 of square miles, being ten times the magnitude of the French empire. Its largest branch, considered as the commencement of the main stream, is called the Maranon, a name which is sometimes applied to the entire river. The main river and its tributaries are navigable at distances of nearly 2500 miles from its mouth, and its width, near its mouth, being nearly 100 miles, it resembles an arm of the sea more than a river.

144. **The tributaries** of this river are severally so considerable in magnitude and importance, that geographers are not agreed as to which of them should be regarded as the main stream, and the name Amazon is generally confined to the part of the river below the confluence of several chief tributaries, which unite nearly at the point where the Rio Negro or Black River joins the Amazons. A view of a good map of this part of Southern America, will give the reader a more clear idea of the course of this river and its tributaries, than could any mere verbal description. The greater tributaries are above twenty in number, all of which are navigable to a point near their sources, while the lesser ones are countless.

Notwithstanding the geographical superiority of the Amazons, and its vast extent of navigable water, it is inferior in commercial importance to the Mississippi; the districts of country traversed by the river and its branches consisting of tracts of natural forest, and uncleared and uninhabited ground.

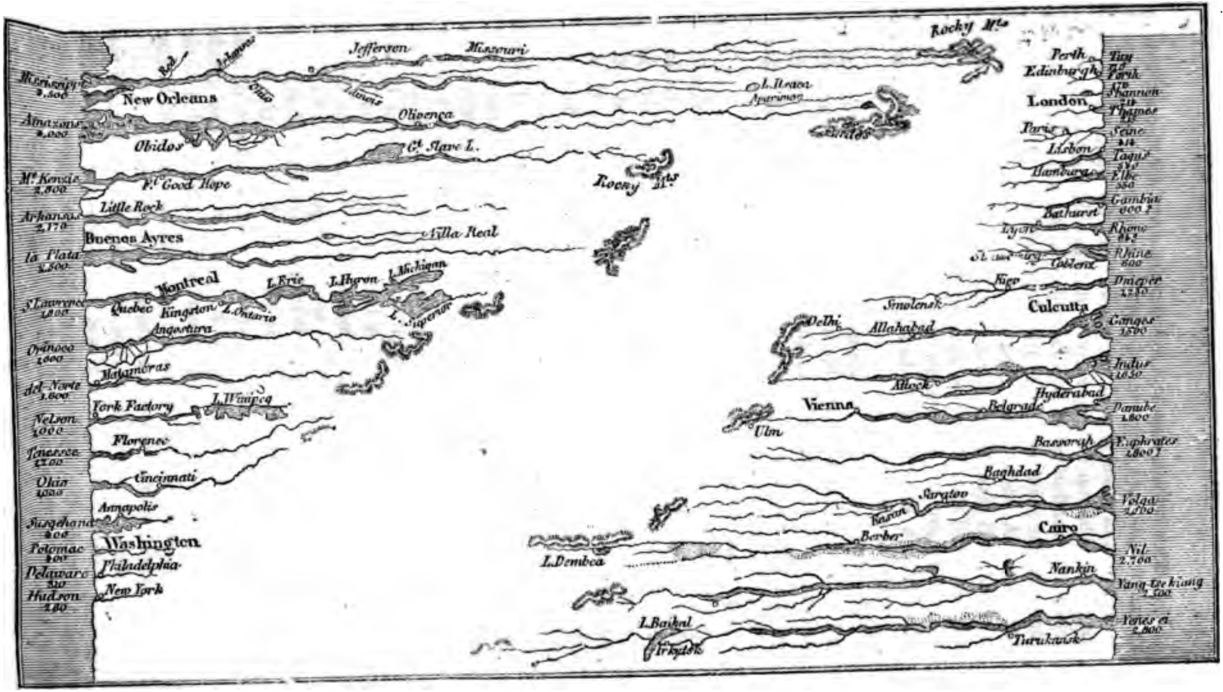
145. **The Orinoco,** another of the great rivers of the southern division of the new continent, drains a valley included between the tableland of Paramo, the eastern chain of the Cordilleras, and the plateau of Caraocas. This river, having its source near that of the Negro, flows first north, and then east, discharging its waters into the Atlantic, through a delta, at the borders of the Caribbean sea, opposite the island of Trinidad.

146. **The Rio de la Plata.**—The third great river of South America is that which near its source is called the Parana, and near its mouth the Plata. It discharges its waters into the South Atlantic, at Buenos Ayres, after having flowed down a valley included between the Andes of Chili and the Brazilian mountains. The length of this river is estimated at 2700 miles, and for 200 miles above its mouth it is nowhere less than 170 miles wide.

147. **The River System of Europe** is as inferior to that of the new continent in geographical, as it is superior to it in commercial and social importance. With the exception of some of the lines of river-communication in the United States, the world can afford no parallel for the spectacle of commercial and social movement presented by the European rivers. The gentle declivities of the water-sheds from which they derive their sources, and the general flatness of the plains over which they flow, are eminently favourable to their commercial utility.

In the western division of Europe, the chain of the Alps and the German mountains form the ridge, along the slopes of which, north and south, the waters flow towards the Atlantic on the one side, and the Mediterranean and Black Sea on the other. In the

Rivers of the Eastern Hemisphere.



Rivers of the Western Hemisphere.

eastern division there is no mountain-chain thus to divide the drainage. A slight and imperceptible elevation of the general plain produces two opposite water-sheds, commencing in a low range of hills separating the sources of the Dnieper from those of the Vistula, and winding along the plain to the tableland of Valdai, which forms its summit, 1200 feet above the level of the sea. The ridge then turns northward towards Lake Onega, and, following a winding course, terminates in the Ural Mountains, about 62° N. lat.

The drainage of the north side of this ridge forms the rivers which flow into the Baltic and the White Sea, that of its southern declivity those which flow into the Black Sea and the Caspian.

148. **General Plan of the Rivers of the World.**—The principal rivers of the world, with their tributaries, their embouchures, and their sources, are exhibited in one general plan on the opposite page, where their lengths are indicated.

CLIMATE.

149. Since the prevailing character of the animal and vegetable kingdoms, in each division of the earth's surface, depends chiefly on climate, it is necessary, on that account alone, independent of many other considerations, that the student in geography should be rendered familiar with the conditions, which in each part of the globe determine the varying vicissitudes and temperature of the seasons.

150. **Dependence of Climate on Latitude.**—The first and chief condition which determines the climate of a country, is its position with respect to the equator. It may be stated, subject to some special qualifications, that the nearer any country is to the Line, or what is the same, the lower its latitude, the higher will be the mean temperature of its seasons.

The reason of this is partly geographical and partly astronomical.

The earth revolves diurnally upon an axis, so directed that the equatorial parts are presented either exactly or nearly to the sun. They are presented exactly to that luminary at the epochs of the equinoxes, in March and September. From March to June they are gradually more inclined from the sun towards the south, the northern hemisphere inclining towards that luminary, so as to receive its rays more directly, and in greater quantity than the southern hemisphere. This inclination of the globe increases constantly from March to June, and then decreases from June to September. The northern hemisphere is thus more and more exposed to the light and warmth of the sun, from March to June; the days during that interval are gradually longer and warmer. It is constantly less inclined from June to September; the days during that interval are gradually shorter and less warm.

Hence it is, that in the northern hemisphere the longest days and highest temperature take place after June, the temperature after March being more moderate. The interval between March and June constitutes, therefore, the spring, and the interval between June and September, when the accumulated effects of heat are greater, the summer.

151. This varying position of the earth towards the sun will be rendered more easily intelligible by illustrative diagrams.

Let N S in these four figures represent the axis of the earth, N being the north, and S the south pole. Let E Q at right angles to N S be the equator, and let S′ be the direction of the sun.

152. In fig. 8 is shown the position of the earth on the 21st of March, the day of the spring equinox. The equator E is then presented exactly in the direction of the sun, the light and heat of which are equally distributed between the two hemispheres.

Fig. 8.

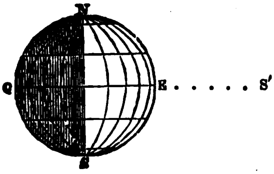
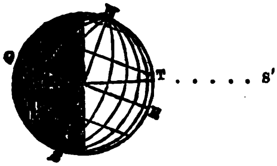
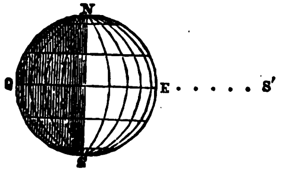


Fig. 9.



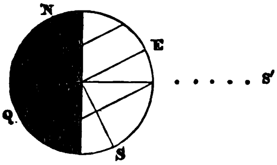
21st June.

Fig. 10.



21st September.

Fig. 11.



21st December.

The boundary of the enlightened hemisphere passes through the poles N and S, and divides into two equal parts all the parallels of latitude. As the earth revolves, therefore, upon its axis, each place upon its surface is during equal intervals exposed to and withdrawn from the sun's light. In other words, the days and nights are equal in all parts of the earth.

CLIMATE.

153. As the earth turns upon its axis N S, all the places upon the equator E Q are brought successively to the point E, directly under the sun. In other words, at all such places the sun is vertical daily at noon.

154. At all other parts of the earth between E and N, or between E and S, the sun is seen at noon obliquely, or what is the same, it is at a distance greater or less from the zenith. And the more distant the place is from the equator, the more distant will the sun be from the zenith at noon.

155. But since the thermal influence of the sun depends in a great degree upon its proximity to the zenith at noon, it follows that this influence will gradually decrease in going from E to N, or from E to S. The temperature, therefore, of the climate at the time of the equinox will gradually diminish as the latitude increases.

But since any two places at equal distances from the equator, north and south, would be presented towards the sun at noon with equal obliquities, it follows that so far as depends on this circumstance, the thermal influence of the sun at places having equal latitudes north and south, will be the same at the time of the equinoxes.

156. The position of the earth with relation to the sun on the 21st of June is shown in fig. 9. The equator E in the interval between the 21st of March and the 21st of June, has gradually declined to the south. The north pole N has consequently been turned more and more towards the sun S′, and the south pole S has been turned more and more from it. In this position, therefore, it is evident that the sun shines more fully on the northern, and less so on the southern hemisphere. The point T, to which it is vertical at noon, is now, not as in the former case upon the equator, but at the distance of 23½° north of it. Places in the northern hemisphere above this point are shone upon by the sun at noon with much less obliquity than places having equal latitudes in the southern hemisphere.

157. The circle which bounds the hemisphere of the earth enlightened by the sun, divides all the parallels of latitude unequally, the larger part of those in the northern hemisphere being enlightened, and the larger part of those in the southern hemisphere being dark.

It follows, therefore, that at this time the days are longer than the nights in the northern, and the nights longer than the days in the southern hemisphere.

158. Now the temperature of the seasons, in any given place, depends conjointly on the altitude to which the sun rises, and on the length of the day; for the greater the altitude is, the more

directly will the solar rays fall upon the place; and the longer the day is, the longer will be the interval during which the thermal influence of the sun is exerted, and the shorter will be the interval during which its presence will be withdrawn.

159. For all these reasons, therefore, on the 21st of June, when the northern hemisphere is most inclined towards the sun, and the southern most inclined from it, the thermal influence of the sun will be greater in the northern, and less in the southern hemisphere, than at any time from the 21st of March to the 21st of June.

During this interval the northern hemisphere is gradually more and more inclined towards the sun, and therefore the length of the day is continually increasing, as well as the altitude to which the sun rises at noon. These two circumstances combine in gradually increasing the thermal influence of the sun from the 21st of March to the 21st of June.

The same circumstances will show that during the same interval, the thermal influence of the sun in the southern hemisphere is gradually diminished; the days being there constantly shorter, and the altitude to which the sun rises at noon constantly less.

After the 21st of June the northern hemisphere is gradually less and less inclined towards the sun, and the southern less and less inclined from it, until at length on the 21st of September, the day of the autumnal equinox, the earth resumes the position, fig. 10, with relation to the sun which it had on the 21st of March, the equator E being then, as before, directed exactly towards the sun.

160. The two hemispheres therefore, as in March, being equally exposed to the sun, receive from it the same thermal influence, and the parallels of latitude being all bisected by the circle which bounds the enlightened hemisphere, the days and nights are equal at all parts of the earth.

Since the altitude to which the sun rises, and the length of the days at equal intervals before and after the 21st of June, are the same, and therefore the thermal influence of the sun also the same, it might be inferred that the temperature of the weather would likewise be the same; and if this inference were just, it would follow that the season from the 21st of March to the 21st of June, would be similar in all its thermal characters to the season from the 21st of June to the 21st of September, except that the succession of temperatures would be developed in a contrary order. Thus it would be expected that the temperature of the weather ten or twenty days after the 21st of June would be identical with its temperature ten or twenty days before the 21st of June.

161. But it is notorious that the thermal phenomena are not at *all in accordance* with this; the season from the 21st of March to the

21st of June, called the Spring, having generally a much lower temperature than the season from the 21st of June to the 21st of September, called the Summer.

Let us see, then, whether we cannot render evident the cause of this.

The temperature of the weather in a given place, depends not exclusively upon the thermal influence exercised by the sun during each day. It must be remembered that when the days are much longer than the nights, and the sun rises to a considerable altitude, a greater quantity of heat is imparted to the atmosphere and to all objects upon the surface during the day, than is lost during the night, and, consequently, an *increment* of heat is given to all such objects every twenty-four hours. The consequence is, that the general effect of the sun's thermal influence during each successive twenty-four hours is to augment the temperature, and thus to increase by accumulation the heat from day to day; and this daily increase will obviously continue until, by the shortening of the days and the decrease of the sun's altitude, the increment of heat during the day becomes equal to its decrement during the night. The day on which that takes place will be the hottest day, because it will be that upon which the daily accumulation will cease. After this, the days being further shortened, and the sun's altitude further diminished, the increment of heat during the day will be less than its decrement during the night, and after each interval of twenty-four hours there will be on the whole a decrease of heat, and so the temperature of the weather will be diminished.

162. Now, from a due consideration of these circumstances, it will be easy to see why the season of summer is warmer than the season of spring, although the sun's altitude and the length of the days are, on the whole, precisely the same both in one season and the other, only succeeding each other in a contrary order. Until the 21st of June the daily thermal influence of the sun continually increases, for the reasons just explained, and it is greater on the 21st of June than on any other day before or after. But although this thermal influence decreases after the 21st of June it is still considerable, and from day to day adds something more or less to the heat already accumulated in the atmosphere, and consequently continues to augment the temperature; and this increase only ceases, when the thermal action of the sun during the day, begins to be counteracted and balanced by the loss of heat during the night.

163. Hence it arises that a certain interval, from the 21st of June to the latter part of July, is generally the hottest part of the summer, being called the *Dog-days*, either because of the

prevalence of canine madness during that period, or because at an early epoch in astronomical history the Dog-star rose before the sun in the morning at that season, and thus harbingered the God of Day. It may even have happened that the Dog-star took its name originally, from the prevalence of canine madness at that season.

164. The circumstances which explain the phenomena of summer in the northern hemisphere, will also explain those of winter during the same interval in the southern hemisphere, since the southern hemisphere at all times is inclined from the sun, exactly as much as the northern hemisphere is inclined towards it, as will be apparent by reference to fig. 9.

165. After the 21st of September (fig. 10), the day of the autumnal equinox, the equator is gradually inclined towards the north, and the northern hemisphere gradually inclined from the sun, and this inclination constantly increases until the 21st of December, when it is greatest, as shown in fig. 11.

The solar rays, as will be apparent from the figure, then fall with greatest obliquity on the northern hemisphere, and with least obliquity on the southern. The parallels of latitude are unequally divided, in both hemispheres, by the circle which bounds the enlightened part of the earth. In the northern hemisphere the greater portions of these parallels are dark, and the lesser portions enlightened, while the contrary takes place in the southern hemisphere. The days are, therefore, shorter than the nights in the northern, and longer in the southern hemisphere; and the sun rises only to low altitudes in the former, but to considerable altitudes in the latter. In fine, all the circumstances show that, in this position of the earth, the summer commences in the southern, and the winter in the northern hemisphere.

166. After the 21st of December, the inclination of the northern hemisphere from the sun gradually and constantly diminishes until the 21st of March, when the equator is once more presented directly to the sun, which affects both hemispheres alike.

Since the 21st of December is the shortest day, and that upon which the sun rises to the least altitude, it is consequently that on which its thermal influence is least, and it might therefore be expected to be the coldest day, and consequently to be midwinter. It is notorious, on the contrary, that the coldest weather is at a later period. This is explained upon the same principles exactly, as those which show why the 21st of June is not the hottest day.

167. The decrement of heat which takes place in the atmosphere owing to the length of the night, the shortness of the day, and the low altitude of the sun on the 21st of December, is greater

than the decrement on any succeeding day; but still on these succeeding days there is still a decrement of heat, though a less one, and therefore on the whole the temperature must continue to fall, and it will so continue until by the increasing length of the day, and the decreasing length of the night, and the increasing altitude of the sun, the increment of heat during the day becomes equal to its decrement during the night; after that takes place, the result of the sun's influence during each twenty-four hours will be on the whole an increase of heat, and the temperature of the weather will accordingly be augmented.

Hence it is that the winter season in the northern hemisphere is the interval between the 21st of December and the spring equinox; the same interval being the summer season in the southern hemisphere.

The altitude to which the sun rises at noon constantly increases until the 21st of June, when it becomes as it were stationary, and afterwards decreases. In the same manner the altitude at noon constantly decreases until the 21st of December, after which it increases, having remained in like manner stationary for a certain interval. These two epochs have therefore been called the solstices, one being denominated the summer, and the other the winter solstice, from a Latin word which signifies the standing or stationary position of the sun.

168. When the northern hemisphere is most inclined towards the sun, as shown in fig. 9, the sun is vertical at noon to all places at 23½° north of the equator. Before that day, and after it, the sun's altitude at noon is less than 90°, and consequently it does not reach the zenith. It may be considered therefore gradually to approach the zenith at such places until the 21st of June, and then gradually to recede from it.

From this circumstance the parallel of latitude which passes through such places has been called the *tropic.*

Similar phenomena are produced at the corresponding parallel of south latitude, and these parallels are accordingly called respectively, the northern and southern tropic, or the *Tropic of Cancer* and the *Tropic of Capricorn.*

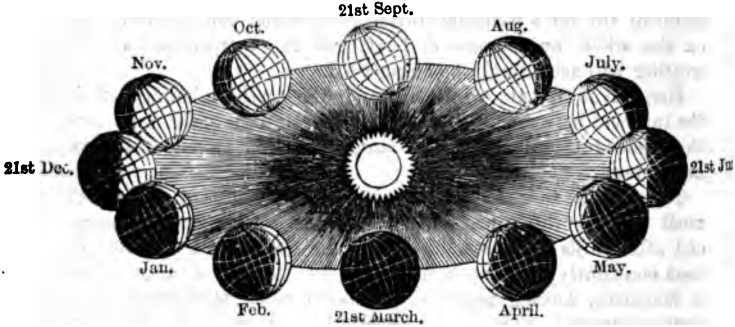
169. It will be evident, by considering the diagrams, fig. 9 and fig. 11, that the sun can never be vertical at noon to any part of the earth except to places which lie between the tropics, and at all such places it is vertical at noon twice in the year.

170. These astronomical causes of the vicissitudes of the seasons may be further illustrated by the diagram, fig. 12, which presents a perspective view of the earth in twelve successive positions which it assumes in one revolution round the sun, the observer being supposed to view it from the north side of the plane of its

orbit. Its motion in that case is in a direction contrary to that of the hands of a clock, or to that of a common screw when turned so as to cause it to move inwards or forwards.

While the globe thus moves round the sun, its axis keeps constantly the same direction, so that in any one position it is parallel to the direction which it had in any other position. On the 21st of June, as shown to the right of the diagram, the northern extremity of the axis, or the north pole, leans towards the sun through an angle of 23½°. If we suppose a parallel of latitude to be described at that distance from the pole, all places within that parallel will receive the light of the sun, and the rotation of the globe on its axis will not throw any of these places upon the dark side of the earth. It follows, therefore, that on the 21st of June the sun does not set at all to any place above that parallel, and there is consequently twenty-four hours day.

Fig. 12.



By referring to the position of the earth, on the extreme left of the figure, which it has on the 21st of December, it will be seen that then the north pole is inclined from the sun, just as much as it was inclined towards it on the 21st of June, and that the same places, bounded by the parallel of latitude 23½° from the pole, which on the 21st of June lay altogether on the enlightened side of the globe, and enjoyed twenty-four hours day, now lie on the dark side, and have twenty-four hours night. As the sun never sets to such places on the 21st of June, so it never rises to them on the 21st of December.

In the positions successively assumed by the earth, in July and August, the north pole is less and less inclined towards the sun, and the part around it, which has no sunset, is limited by a less and less parallel of latitude. On the 21st of September, the equator *being* presented to the sun, there is no part around the pole which has continual day, all places being twelve hours exposed to the sun, and twelve hours removed from it.

After the 21st of September, the north pole begins to incline from the sun, and in October, a small portion around it is entirely deprived of the sun's light. This portion, thus involved in continual night, constantly increases in extent until the 21st of December, when it extends to the parallel of latitude already mentioned. After the 21st of December, the north pole is less and less inclined from the sun, so that the portion involved in continual night is less in January, and still less in February, and on the 21st of March, as on the 21st of September, there are twelve hours day and twelve hours night to all places.

After the 21st of March, the north pole begins again to lean towards the sun, and a portion of the earth around it enjoys continual day, this portion increasing in extent during the months of April and May, and attaining its greatest magnitude on the 21st of June, when its extent, as already explained, is a circle 23½° from the pole.

171. The parallel which is 23½° from the pole, is 66½° from the equator, and consequently has the latitude north of 66½°.

This parallel of latitude is called the *Arctic* or *Polar Circle*, and the polar region included by it is called the *Frigid Zone.*

All the circumstances, which are here explained, respecting the north polar region, circumscribed by the arctic circle, will be equally applicable to the corresponding region, circumscribed by a circle 23½° from the south pole. Such a circle is called the *South Polar* or *Antarctic Circle*, and the polar region circumscribed by it is the *Southern Frigid Zone.*

172. Although the diurnal and nocturnal phenomena of the two frigid zones, northern and southern, are precisely the same, they are not simultaneous, those which are identical being produced at opposite epochs of the year, as will be rendered evident by examining attentively the several positions of the illuminated and dark hemispheres of the globe in the successive months, in fig. 12. When the entire north polar circle is enlightened on the 21st of June, the entire south polar circle is dark. There is continual day in the one, and continual night in the other. On the contrary, when the entire north polar circle is dark on the 21st of December, the entire south polar circle is enlightened. There is continual night in the one, and continual day in the other.

The phenomena on the 21st of June, therefore, in the northern frigid zone, are identical with those of the 21st of December in the southern frigid zone, and *vice versâ.*

In the like manner, there is just so much of the northern polar region enlightened, and of the southern polar region darkened, in July, as there is of the northern polar region darkened, and the southern enlightened, in January. The diurnal and nocturnal vicissitudes, therefore, of the northern frigid zone in July, are identical with those of the southern frigid zone in January, and *vice versâ*.

If the reader will take the trouble of following the position of the earth from month to month, as shown in fig. 12, he will be able to satisfy himself, that at all intervals of six months the vicissitudes of light and darkness are in the same way reciprocated between the two frigid zones.

It might be inferred, that the continual presence of the sun above the horizon, would necessarily produce a great calorific effect; and at least during that portion of the year, during which they are respectively inclined towards the sun, the polar circles would enjoy intense heat. That such, however, is not the case is easily explained. The heat imparted by the sun to any part of the earth exposed to its influence, depends, as already stated, on two conditions: first, the altitude to which it rises, and secondly, its continuance above the horizon, or the length of the day. But the former condition has a vastly greater influence upon the thermal effects than the latter. Although, therefore, the continuance of the sun above the horizon, at the polar circles, is favourable to the development of heat, yet the very low altitude to which it rises counteracts this effect; so that within the polar circles, even with the influence produced by the continuous presence of the sun, the general temperature is invariably below that at which water freezes.

It is from this continuance of a temperature so low that the frigid zone has taken its name.

173. **Torrid Zone.**—The part of the earth included between the tropical circles, which comprises all places having a latitude less than 23½°, is called the *Torrid Zone*.

Although the exposure of these regions to the heat of the sun varies within certain limits between December and June, being most completely presented to that luminary in March and September, they, nevertheless, receive the solar influence in a much more powerful degree, than the parts of the globe having higher latitudes in the one hemisphere and the other.

It is demonstrated in physics, that the heating power of the sun's rays falling upon any object increases in proportion as they approach to the perpendicular direction upon it. At the time of the equinoxes, therefore, the noon-day sun upon the Line, projecting its rays perpendicularly downwards, produces the greatest possible calorific effect.

At these times, also, the sun, rising precisely in the east, ascends the heavens at right angles to the horizon, until at noon it reaches the zenith; after which it descends perpendicularly in like manner, and sets precisely in the west.

174. **Sun vertical twice a year in the Torrid Zone.**—Every point of the torrid zone is presented, at one period or another of the year, directly to the sun, so that there are two days in the year upon which the sun at noon is vertical at such places, and its extreme departure from the zenith at noon is always very limited. Thus to places on the Line, the sun at noon never departs from the zenith more than 23½°, and even at the limits of the torrid zone, that is, at the latitude 23½° north or south, the sun which on the 21st of June is vertical at noon in the northern, and on the 21st December in the southern hemisphere, is not more than 47° from the zenith at noon on the 21st of December in the northern, and on the 21st of June in the southern hemisphere; for all places within the tropics the extreme distance of the sun from the zenith at noon must always be less than 47°.

Indeed it may be stated generally, that for places between the tropics, the greatest distance of the sun at noon from the zenith will be found by adding 23½° to the latitude of the place, and that twice in the year it passes through the zenith at noon.

When it is considered that the temperature of the weather mainly depends on the distance of the sun from the zenith at noon, increasing as that distance decreases, it will be easily understood why the climate of the torrid zone is characterised by that extremely elevated temperature from which it takes its name; for although the sun at noon, during a certain part of the year, is at a distance more or less considerable from the zenith, the interval during which it has this distance is comparatively short, and that during which it is in or near the zenith much more considerable.

The hottest seasons occur, not as might be first supposed, upon the Line, but at and within a limited number of degrees of the tropics; because at such latitudes the sun at midsummer continues to cross the meridian very near to the zenith for a much more considerable time than on the Line at the epochs of the equinoxes, where its change of declination is much more rapid.

175. **Temperate Zone.**—The parts of the globe included between the limits of the torrid and frigid zones,—that is between the latitudes 23½° and 66½°,—is exempt from the extremes of temperature which characterise the one and the other of these regions. Within its limits the sun never ascends to the zenith, nor on the other hand are the phenomena of continuous day or

continuous night ever witnessed. The warmth of summer is produced by long days, combined with moderate meridian altitudes, and the rigour of winter is mitigated by the presence of the sun above the horizon for a considerable interval, even on the shortest days.

It must not be understood, that within the limits of what is thus called the temperate zone, the climates are uniformly the same. On the contrary, in approaching those limits, at which it is united with the torrid and the frigid zones, the character of the climates approach gradually to those peculiar to the one extreme zone and the other, so that the climates of the higher latitudes of the temperate zone differs but little from those of the lower latitudes of the frigid zone, while those of the lower latitudes of the temperate zone, approximate gradually and insensibly to those of the higher latitudes of the torrid zone. In fact, within the limits of the temperate zone are included a much greater variety of climates than any which characterise either of the extreme zones.

VI.—TURKEY—GREECE.

THE SURFACE OF THE EARTH,

OR FIRST NOTIONS OF GEOGRAPHY.

CHAPTER IV.

176. Climate, dependent on elevation.—177. Vegetation of the Himalayas.—178. Vegetation of the Andes.—179. Animals of the tropics.—180. The Himalayas—Animals inhabiting them—181. The local character of climate.—182. Heat received from celestial spaces.—183. Why the temperature of the earth is not indefinitely increased.—184. Effect of clouds.—185. Effect of contact of air and earth.—186. Thermal effects of a uniform surface.—187. Why this regularity does not prevail. MOUNTAINS.—188. Maps and globes in relief.—189. Johnston's Physical Maps.—190. Mountain ranges not uniform.—191. Spurs.—192. Relief of the earth's surface.—193. Effect of the contemplation of mountain scenery.—194. The Pyrenees.—195. The Alps.—196. Average height of continents.—197. New mountain ranges possible. THE OCEAN.—198. Greatest depth.—199. Uses of the ocean.—200. General system of evaporation and condensation.—201. Climatic effects.—202. Ocean currents.—203. Antarctic drift current.—204. Its equatorial course.—205. Gulf stream.—206. Course and limits of ocean currents evident.—207. Ocean rich in animal life.—208. Moral impressions.

176. Climate dependent on elevation. Snow Line.—It has been explained in our Tract on Terrestrial Heat, that as we ascend into the atmosphere from the level of the sea, the mean temperature gradually decreases, and beyond a certain elevation it falls even below the freezing point of water; above this limit, therefore water cannot exist in the liquid state, and must assume the state of snow or ice. Such an elevation is accordingly designated the limit of perpetual snow, and it is marked on all lofty mountains by the limits of their snow-covered sides. This boundary is accordingly called the *Snow Line*.

It may be stated as a general fact, subject nevertheless to some local qualification, that the elevation of the snow-line is greatest at those parts of the earth, where the climate at the level of the sea is hottest, and that its elevation decreases with the decrease of the mean temperature of the same level. The snow-line, therefore, has the greatest elevation within the tropics, and decreases gradually with the increase of latitude, until at the polar circles it falls to the surface.

Since climate therefore varies, not only with the latitude but with the elevation of the place above the level of the sea, it follows that in mountainous regions a variety of climates will prevail, depending on the elevation of the summits. If that elevation exceed the limits of the snow-line, all varieties of climate between that which characterises the sea level, or which is natural to the plateaux on which the mountains stand, and the climate of the poles are found, and consequently a corresponding variety of natural productions, vegetable and animal, and corresponding susceptibilities of culture prevail. This is a circumstance which gives much interest to mountainous countries, and often confers upon them great commercial and social advantages.

It is evident, also, that the higher the mean temperature of the plateaux is upon which snow-capped mountain ranges stand, the greater will be the varieties of climates exhibited between their summits and their bases, and the greater consequently will be also the variety of natural productions and artificial culture. Hence arises the magnificent display of vegetation exhibited in those ranges of the Andes and Cordilleras, and other lofty ridges which intersect the torrid zone.

177. Vegetation of the Himalayas.—Although the chain of the Himalayas far exceeds in elevation the Andes and Cordilleras of South America, they are thus, from their geographical position, being situate far beyond the limits of the torrid zone, excluded from the advantages here noticed, and they present none of *that in*exhaustible variety of phenomena by which the ridges which rise to such vast altitudes from the plateaux of the torrid zone are characterised. Beautiful as are the valleys of Kumaoon and Nepaul, they are not signalised by the presence of a single palm-tree. On the southern slope of the Paropamisan range, which extends over 350 miles of Persia and Afghanistan, and separates the deserts of Yezd and Turkestan, Nature nowhere displays that profusion of arborescent grasses, tree-ferns, heliconias, and orchideæ which are witnessed on the higher plateaux of the tropical mountains. On the slopes of the Himalayas, under the shade of the deodar and the large-leaved oak peculiar to these Indian alps, the rocks of granite and mica-schist are clothed with forms closely resembling those which characterise Europe and northern Asia. The species indeed are not identical, but they are similar in their aspect and physiognomy, including junipers, Alpine birches, gentians, parnassias, and prickly species of ribes. The chain of the Himalayas is also wanting in those imposing volcanic phenomena, which in the Andes and the Indian Archipelago often recall to the inhabitants, in characters of terror, the existence of forces developed within the globe. Moreover, on the southern declivity of the Himalayas, where the vapour-loaded atmosphere of Hindostan deposits its moisture, the region of perpetual snow descends to a zone the elevation of which does not exceed 13000 feet. Thus the region of organic life ceases at a limit 3000 feet lower, than that to which it extends in the equinoctial portion of the Cordilleras.

178. **Vegetation of the Andes.**—The mountainous regions of the Tropics present a further advantage in being that part of the globe, as already mentioned, where the greatest possible variety of impressions are produced by the contemplation of nature. In the Andes of Cundinamarca, Quito, and Peru, furrowed by deep barrancas, it is given to man to behold at once all the plants of the earth, and all the stars of the firmament. There, at a single glance, the beholder sees lofty feathered palms, humid forests of bamboos, and all the beautiful family of musaceæ, and, above these tropic forms, oaks, meddlars, wild roses, and umbelliferous plants, as in our European homes. There, too, both the celestial hemispheres are open to his view, and when night arrives, he sees displayed together the constellation of the Southern Cross, the Magellanic clouds, and the guiding stars of the Bear, which circle round the Arctic Pole. There the different climates of the earth, and the vegetable forms of which they determine the succession, are placed one over the other, stage above stage, and the laws of the decrement of heat are indelibly written, on the rocky walls and rapid slopes of the Cordilleras, in characters easily legible to the intelligent observer.

Not only is the torrid zone by the abundance and luxuriance of its organic forms most rich in powerful impressions, but it presents another and greater advantage, in the uniform regularity which characterises the succession of its meteorological and organic changes. The well marked lines of elevation which separate the different forms of vegetable life, demonstrate in a striking manner the same play of general and invariable laws, which govern the celestial motions reflected in terrestrial phenomena. Thus, in the burning plains which stretch nearly on the level of the sea in these regions, we behold in profusion the families of bananas, of cycadaceæ, and of palms, of which the number of species included in the Floras * of the tropical regions, has been so wonderfully augmented by modern botanic travellers. To these succeed, on the slopes of the Cordilleras, in the mountain valleys, and in humid and shaded clefts of the rocks, tree-ferns raising their thick cylindrical stems, and expanding their delicate foliage, whose lace-like indentations are seen projected against the deep azure of the firmament. There, too, flourishes the cinchona, whose fever-healing bark is deemed the more salutary, the oftener the trees are bathed and refreshed by the light mists, which form the upper surface of the lowest stratum of clouds.

Immediately above the region of the forests the ground is covered with white bands of flowering social plants, small aralias, thibaudias, and myrtle-leaved andromedas. The alp-rose of the Andes, the magnificent befaria, forms a purple girdle round the spiry peaks. On reaching the cold and stormy regions of the Paramos, shrubs and herbaceous plants, bearing large and richly-coloured blossoms, gradually disappear, and are succeeded by a uniform mantle of monocotyledonous plants. This is the grassy zone, where vast savannahs clothe the high tablelands and the wide slopes of the Cordilleras, whence they reflect a yellow hue,—savannahs, on which graze llamas and cattle descended from those formerly brought from the Old World. Trachytic rocks next appear forcing the turf and rising high into those strata of the atmosphere containing a less proportion of carbonic acid, and supporting only plants of inferior organisation, such as the lichens, the lecideas, and the many-coloured dust of the lepreria, which forms small round patches on the surface of the stone.

Scattered patches of fresh fallen snow arrest the last feeble traces of vegetation, and are succeeded by the region of perpetual snow, of which the lower limit is distinctly marked, and undergoes but little change.

* The collection of vegetable productions natural to a country is called its *flora*, and that of the animals indigenous to it its *fauna*.

The elastic subterranean forces strive, for the most part in vain, to break through the snow-clad domes which crown the ridges of the Cordilleras, but even where these forces have actually opened a permanent channel of communication with the outer air, either through crevices or circular craters, they rarely send forth currents of lava, erupting more frequently ignited scoriæ, jets of carbonic acid gas, sulphuretted hydrogen, and steam.*

179. **Animals of the tropics.**—A corresponding variety is found in the animal kingdom in these regions at the level of the sea; upon the plains which extend over the tropical regions are found the varieties of monkeys, crocodiles, the boa-constrictor, rattlesnake, jaguars, and macaws. Higher up, at a level rising from 5000 to 10000 feet, at the base of the Andes, are found the ocelot, the strutheo rea, and the duck. Higher still, the ape, the puma, and the llama, and, in fine, about the snow-line, hawks, vultures, bears, and the condor, which rises upon its vast wings above the lofty summits of Chimborazo and Aconcagua.

180. **The Himalayas** are characterised, also, by animals dwelling in a succession of stages one above the other. Thus, upon the plains are found the tiger, the peacock, and the Bactrian camel. Higher up the bat, the Cashmere goat, and the pheasant, and just below the snow-line, the sheep, the yak, the pigeon, the robin, &c.

181. **The local character of a climate** depends on the mean temperature of the atmosphere and of the surface of the earth. And this temperature itself must depend chiefly on the heat imparted to the atmosphere and the earth by the sun. The solar rays, in passing through the atmosphere to the earth, impart to that very attenuated and transparent fluid an inconsiderable quantity of heat, their chief thermal power being exerted on the surface of the earth, which forms the base of the atmospheric ocean. The earth, like all bodies, absorbs a certain proportion of the heat thus transmitted to it, and what it fails to absorb it reflects exactly as a surface would reflect light. The heat which it reflects, not entering it, does not affect its temperature, and it is warmed exclusively by the portion it absorbs. This portion is so considerable, that if it were uniformly diffused over the entire surface of the earth, it would be sufficient to dissolve annually a shell of ice 100 feet thick covering the entire globe.

182. **Heat received from celestial spaces.**—But besides the heat received from the sun, the earth also receives a considerable portion of heat from the surrounding firmament, in other words,

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* Humboldt's Cosmos. Introduction.

from the countless myriads of suns composing the stellar universe which are seen nightly sparkling in the heavens; and this latter source of heat differs from that of the sun, inasmuch as all parts of the earth are constantly exposed to it night and day, whereas they are only exposed to the direct influence of the sun during average intervals of twelve hours.

It has resulted from the experiments and observations of M. Pouillet, that the quantity of heat thus received by the earth from the celestial spaces is such, that if it were uniformly diffused over the surface it would be sufficient to melt a shell of ice, enveloping the earth, 85 feet thick.*

183. **Why temperature of the earth is not indefinitely increased.**—It may be asked, therefore, how it happens that if the earth receive and absorb an annual quantity of heat so enormous, its temperature is not raised to such a point as to be incompatible with the continued existence of the organised world upon it. It might be expected that the heat absorbed in the torrid zone, being transmitted by the process of conduction through the solid matter composing the earth to the colder regions of the poles, would first dissolve all the ice there collected, and then gradually raise the temperature of the polar regions, to which the animal world would first take refuge flying from the scorching region of the tropics, and which would become at the same time the theatre of the present flora of the temperate and tropical zones, and later would be raised to a temperature destructive of all organisation.

Such a catastrophe is prevented, and the thermal condition of the globe maintained within the necessary limits, by a remarkable property with which matter has been endowed by its Maker, in virtue of which all bodies possess the quality of thermal radiation, in the exact proportion in which they are endowed with that of thermal absorption. The heat, therefore, which every part of the surface of the earth absorbs from the solar rays, it throws back by the process of superficial radiation, and if the atmosphere were everywhere cloudless, the heat thus radiated back would pass into the celestial spaces, and the atmosphere would then, in spite of the solar rays passing through it, remain at a very low temperature.

184. **Effect of clouds.**—The existence of clouds, however, modifies this. The heat radiated from the surface of the earth is in a great degree intercepted, and prevented from escaping into the celestial regions, by the clouds, which reflect and radiate it back again to the earth through the lower strata of the atmosphere; and thus these thermal rays, being reverberated between the

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* See Tract on Terrestrial Heat, Museum, vol. 3, p. 65.

clouds and the surface, warm the lower strata of the atmosphere through which they are so frequently transmitted.

185. **Effect of contact of air and earth.**—But the atmosphere also receives heat from the earth, by the contact of its lowest strata with those parts of the terrestrial surface, which have a higher temperature. When these lowest strata are thus warmed by contact, they ascend as heated air does in a chimney, air having a lower temperature flowing in to take their place.

It is by these several means therefore, much more than by the direct influence of the sun, that the temperature of the atmosphere is maintained and regulated.

186. **Thermal effects of an uniform surface.**—If the whole surface of the earth consisted of one homogeneous material, whether solid or fluid, and were in one uniform condition, its powers of reflection and absorption, and consequently its power of radiation, would be everywhere the same. In that case the thermal influence of the sun, governed by no other conditions than those of its altitude and continuance above the horizon, would necessarily be the same at all points of the same parallel of latitude, since, at all such points, the sun's altitude and the length of the day are necessarily the same. The equator and each parallel of latitude would then be isothermal lines, a word which expresses a line upon the surface of the earth, all points of which have the same mean temperature. Not only would the mean temperatures of all points on the same parallel be the same, but the extreme temperatures of summer and winter would likewise be the same. In other words, all places having the same latitude would, under the conditions supposed, have identically the same climate. They would have the same average annual temperature, and would be subject to the same vicissitudes of seasons.

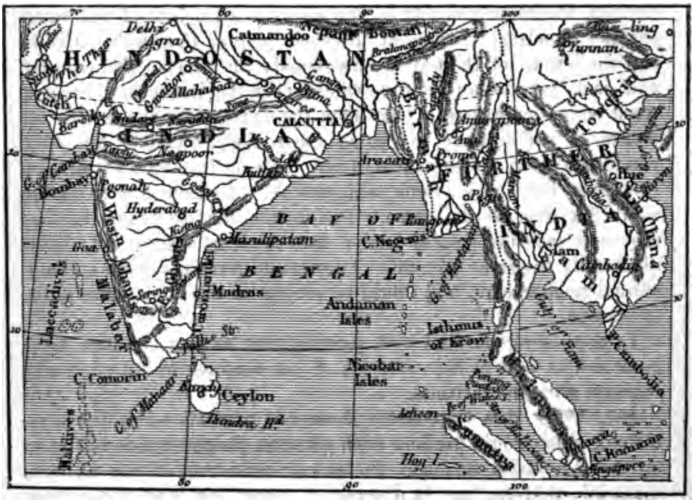
In comparing parallel with parallel, the average annual temperature, as well as the extremes of the seasons, would regularly increase with the latitude.

187. **Why this regularity does not prevail.**—But the conditions which would produce such climatic phenomena do not exist on the terrestrial surface. Instead of consisting of one uniform material, that surface is diversified,—first, by land and water; and secondly, the land itself is still more diversified in its character, according as it is more or less clothed with vegetation, and even where it is destitute of vegetation, it varies according to the quality of the rocks or other strata which compose its uncovered surface. The reflecting, absorbing, and therefore radiating powers of the land,are infinitely diversified. In general the foliage of vegetation is a powerful radiator, while the naked

soil, or rocks, are comparatively feeble radiators and stronger reflectors. The water of the ocean, which covers three-quarters of the terrestrial surface, is much more uniform in its thermal properties than the land. But even those properties of the ocean are modified by the congelation which takes place on so vast a scale in the frigid zone.

All these circumstances combined, and many others which can only be fully understood by a more profound study of physical geography, render the actual climatic phenomena extremely different from those which would depend on the latitude alone, and which would be developed on a globe the superficial materials of which would be uniform.

The departure of the lines of equal, mean, and extreme temperatures from the parallels of latitude, has been already explained in our Tract upon Terrestrial Heat, and it will not, therefore, be necessary to insist further upon them here.



VII.—INDIA.

MOUNTAINS.

188. **Maps, and Globes in Relief.**—Elementary instruction in geography has been hitherto for the most part limited to the description of the outlines of land and water. The varieties of form depending on relief have been comparatively neglected. This has arisen most probably from the difficulty of presenting to the student visible representations of such forms. Maps and globes, showing in moulded relief the inequalities of the land, have indeed been constructed, and with suitable explanations may be found useful to the teacher and the pupil. Independently, however, of their cost, which is necessarily considerable, they are subject to grave objection, owing to the enormous violation of proportion between the vertical and the horizontal dimensions, which they must necessarily exhibit. It has been explained elsewhere, that the elevation of the most lofty mountain-summits does not exceed the 1600th part of the Earth's diameter, and consequently such a summit, if formed in relief in its just proportion on a 16-inch globe, would be represented by a protuberance not exceeding the hundredth part of an inch. All maps and globes, therefore, presenting the inequalities of the land in moulded relief, must, in order to render them perceptible at all, give the vertical magnitude exorbitantly disproportionate to the horizontal dimensions. When such illustrations are used for the purpose of elementary instruction, the teacher should be careful to impress upon the mind of the pupil this inevitable departure from the natural proportions.

189. **Johnston's Physical Maps.**—The expedient adopted in the physical maps of Mr. A. K. Johnston renders them exempt from this objection, although the same vivid illustration of the superficial inequalities is not presented by them. In these the plains, valleys, and lowlands are coloured green, the elevated plateaux and table-lands brown; and the mountain-ridges and peaks are distinguished by obvious marks indicative of their relative altitudes, the actual heights being marked in numbers of English feet. The sea is also everywhere distinguished from the land by its blue colour. As a physical illustration, these maps are therefore, as I conceive, as perfect as the nature of the subject of instruction allows.

190. **Mountain-ranges not uniform.**—Although each of the great continental systems, which have been already described, is characterised by a certain prevailing direction, it must not be supposed that it follows one uniform and unbroken course, or even that it consists of a single uninterrupted series. They are, on

the contrary, liable to frequent changes of direction, are in many places discontinuous, and are subject to still greater irregularity in both height and width.

191. **Spurs.**—Each main ridge also throws out lateral ramifications at various angles with its general direction, called *spurs.* Those are often themselves considerable chains of mountains, throwing off secondary spurs parallel to the primary chain, or nearly so. These subordinate ranges, intersecting each other at various angles, and broken by valleys and ravines, form a reticulation, which usually covers a vast extent of country stretching out at either side from the base of the principal chain. They decrease gradually in their dimensions, both horizontal and vertical, with their distance from the parent chain. Every one who has visited the country on either side of the ranges of the Alps, the Pyrenees, or Mount Atlas, will be familiar with these features.

192. **Relief of the Earth's surface.**—Considering the Earth as a globe formed of solid matter, subject to superficial inequalities, and partially covered with water, the land must be regarded merely as the more elevated parts rising out of the waters, which, according to the common law of gravitation, are lodged upon the lowest levels. The level parts of the land must be considered as plateaux, table-lands, or terraces formed upon vast mountains, the bases of which are at the bottom of the Ocean.

The mountains, in like manner, which rise from the surface of the land, must be considered as only the highest peaks of those whose bases are established upon the bottom of the deep, and the plains around them, upon which they rest, as merely terraces or plateaux forming steps, as it were, in ascending their acclivities.

In accordance with these views, it is found that systems of mountains, whether they form continued chains, detached groups, or isolated peaks, seldom have their bases upon a low level. On the contrary, the plains upon which they stand are almost always plateaux or tablelands at a considerable altitude above the level of the sea. The heights of mountain-summits being always expressed with relation to the level of the sea, it must therefore be remembered, that in estimating heights above the general level of the plains on which the mountains stand, it is necessary to deduct the heights of such plains from the tabulated heights of the mountains.

That this correction is of importance, will be comprehended when it is remembered, that the heights of the tablelands upon which the great chains of mountains stand, above the level of the sea, varies from 2000 to 12000 feet. Thus, for example, the tabulated altitude of Kunchinjunga, the highest peak of the *Himalayas,* and indeed the most lofty point hitherto discovered on the globe, is 28178 feet; but the tableland of Thibet, on which it stands, has an altitude of about 11000 feet, so that the height of the peak above the level of the surrounding plain is only 17000 feet.

In like manner, the height of Mont Blanc is 15739 feet, but the height of the Lake of Geneva being 1450 feet, and the base of Mont Blanc being several hundred feet more, it follows that the summit of Mont Blanc cannot be much more than 13000 feet above the level of its base.

From the two examples here given, it will be apparent how little relation the tabulated heights of mountains sometimes have, to the appearance which they would present to an observer. The highest peak of the Himalayas, measured from the level of the sea, is nearly double that of Mont Blanc, and is sometimes therefore described as being a mountain, such as would be produced by piling two like Mont Blanc one upon the other. Such an illustration, nevertheless, is most inappropriate, as appears from what has been just stated, since an observer of Kunchinjunga must necessarily view it from a station about 11000 feet above the level of the sea, while an observer of Mont Blanc can view it from a station less than 2000 feet above that level. Mont Blanc would, therefore, under these circumstances, have nearly as great an apparent height as Kunchinjunga.

193. **Effect of the contemplation of mountain scenery.**—The more the imagination and understanding are impressed with the lofty and massive mountain ranges—as evidences of great terrestrial revolutions which the globe has undergone at distant epochs of its history—as the limits of varying climates—as the lines of separation forming the watersheds of opposite regions—and in fine, as the theatres of peculiar vegetation—the more necessary is it to obtain a correct numerical estimate of their actual volume, so as to demonstrate the comparative minuteness of their mass beside that of the extensive platforms on which they stand.

194. **The Pyrenees.**—Take, for example, the chain of the Pyrenees, the area of whose base and whose mean elevation have been determined with great precision. Let us suppose that this entire mountain mass were spread equally over the whole surface of France, and let it be required to determine what would be the thickness of the stratum which it would then form. Nothing can be more simple than such an arithmetical problem, and the result of its solution is, that the whole surface of France would be raised only 115 feet.

195. **The Alps.**—In like manner, if the chain of the Alps were levelled, and the material composing it uniformly spread over the whole surface of Europe, it would form a stratum only 21⅛ feet thick.

196. **Average height of continents.**—Baron Humboldt, by an elaborate calculation, obtained a pretty exact estimate of the average height of the surface of the land, composing the principal divisions of the world above the level of the sea. He found that the average height of the land in Europe is 670 feet. In North America, 748 feet. In Asia, 1132 feet; and in South America, 1151 feet.

These results demonstrate that the land in the southern regions is more elevated than in the northern. In Asia the low elevation of the extensive plains or steppes of Siberia, is compensated by the mountain masses between the parallels of 28½° and 40° lat., extending from the Himalaya to the Kuenlun of Northern Thibet, and to the Tianschian or Celestial Mountains. Some idea may be formed from these calculations in what parts of the globe the action of subterranean plutonic forces, as manifested in the upheaval of continental masses, has been most intense.

197. **New mountain ranges possible.**—"There is no sufficient reason," observes Humboldt, "why we should assume that the subterranean forces may not, in ages to come, add new systems of mountains to those which already exist, and of which Elie de Beaumont has studied the directions and relative epochs. Why should we suppose the crust of the earth to be no longer subject to the agency, which has formed the ridges now perceived on its surface? Since Mont Blanc, and Monte Rosa, Sorata, Illimani, and Chimborazo, the colossal summits of the Alps and the Andes are considered to be amongst the most recent elevations, we are by no means at liberty to assume that the upheaving forces have been subject to progressive diminution. On the contrary, all geological phenomena indicate alternate periods of activity and repose; the quiet which we now enjoy is only apparent; the tremblings which still shake the surface in every latitude, and in every species of rock—the progressive elevation of Sweden, and the appearance of new islands of eruption—are far from giving us reason to suppose that our planet has reached a period of entire and final repose."

[illegible] OCEAN.

19[illegible] while the aerial ocean invests the entire [illegible] a depth of from forty to fifty miles, [illegible] already explained, covers only about [illegible] surface, being deposited according to the [illegible] in the low[illegible] According to the result [illegible] character of the solid surface which it covers is quite analogous to that which rises above its surface, being similarly varied by hill and valley, mountain and plain. The greatest depth of the ocean is still undiscovered. The plumb-line, in one part of the Pacific Ocean, was let down to the depth of 27600 feet by Sir James Ross without finding bottom. It has been generally assumed, as most probable, that the greatest depth of the ocean does not differ much from the greatest elevation of the land above its surface, which being in round numbers five miles, would show that the extreme difference of level of the solid surface of the globe does not exceed ten miles, or about the 800th part of its diameter.

V.—THE SPANISH PENINSULA.

199. **Uses of the ocean.**—The vast collection of water forming the ocean ministers in an infinite variety of ways to the maintenance of the organised world, and in none more so than in its property of evaporation. It may be considered in a certain sense as a vast apparatus of distillation, by which fresh water is supplied in regulated quantity and suitable quality to all parts of the land, and in these phenomena the mountains play a conspicuous part.

200. **General system of evaporation and condensation.**—It is demonstrated in physics that when an aqueous solution is exposed to the atmosphere, the pure water which forms the chief

part of it will be converted into vapour at the surface in contact with the air; and the rate of such evaporation, other things being the same, will be proportionate to the extent of the surface, the temperature of the air in contact with it, and the superficial temperature of the solution.

The water of the ocean is a solution of certain salts and alkaline substances. The evaporation which takes place from its surface affects only the pure water, leaving the saline and other similar constituents still dissolved in it. The pure aqueous vapour thus taken into the atmosphere, rising to the more elevated strata, is transported by atmospheric currents, and attracted by the mountain summits and other elevated parts of the land, upon which it is precipitated in the form of rain or snow, from which streams flow down the declivities, discharging the functions of irrigation, and thus contributing to the maintenance of animal and vegetable life upon the land.

201. **Climatic effects.**—Independently of the obvious advantages which the ocean affords, as supplying the means of intercommunication by commerce between distant parts of the earth, it also serves an infinite variety of purposes in the climatic economy of the globe. It has been already shown that from the uniformity of its physical qualities, it has a tendency to equalise and regularise climate, so as to bring the isothermal lines into closer proximity with the parallels of latitude.

202. **Ocean currents.**—Its liquid properties, however, combined with the effects of temperature, render it further subservient to the general equalisation of the temperatures of the extreme zones, moderating the heat of the torrid and the cold of the frigid. This is accomplished by the great ocean currents, the existence, directions, and limits of which have been ascertained by modern navigators.

These currents are classed as constant, periodical, and variable, the two latter classes being determined chiefly by the influence of the winds and tides.

203. **Antarctic drift current.**—The constant currents which are by far the most important, have their origin chiefly in the southern frigid zone, from which a vast stream called the *antarctic drift current*, pours its cold waters first northwards into the Pacific and then eastwards towards the eastern coast of South America. Striking upon the shores of Chili, opposite the island of Juan Fernandez, it is diverted to the north, following the coast of the South American continent, until it encounters the jutting shores of Peru, by which it is turned westward, where it takes the name of the equatorial current.

204. **Its equatorial course.**—From that point, following the

direction of the line westward, and passing among the islands of the Indian Archipelago, it traverses the Indian ocean, and sweeping round the Cape of Good Hope, turns northwards along the west coast of Africa, until it encounters the shores of the Gulf of Guinea, which again divert it westward, where it resumes the name of the equatorial current. Traversing the Atlantic, it arrives at the northern coast of South America, and enters the Caribbean Sea through the chain of the West India islands, from which it arrives in the Gulf of Mexico.

205. **Gulf stream.**—In this long course, after cooling the waters of the tropical ocean, its own temperature is at length raised to a high point, and in that thermal state it arrives in the Gulf of Mexico. The direction of the current is there changed by the southern coast of North America, and it issues through the channel between Cuba and Florida, flowing northward along the coast of the United States, and about the 35th degree of latitude turning north-east, it again traverses the Atlantic, dividing its course into two branches, one directed between the British Isles and Iceland to Spitzbergen in the Arctic ocean, and the other by the Azores and Madeira back to the coast of Morocco.

At the point where it issues from the Gulf of Mexico, the current takes the well-known denomination of the *Gulf stream.* Its temperature, as just stated, is so elevated that its existence can readily be determined by navigators by means of the thermometer. It becomes thus a means of transporting to the regions of the northern frigid zone a portion of the tropical heat, so as to produce the equalising effect already mentioned.

206. **Course and limits of ocean currents evident.**—"The currents of the ocean," observes Humboldt, "present a remarkable spectacle, maintaining a nearly constant breadth. They cross the sea in different directions, like rivers of which the adjacent undisturbed masses of water form the banks. The line of demarcation between the parts in motion, and those in repose, is most strikingly shown in places where long bands of sea-weeds, borne onward by the current, enable us to estimate its velocity. Analogous phenomena are sometimes presented to our notice in the lower strata of the atmosphere, when, after a violent storm, the path of a limited aerial current may be traced through the forest by long lanes of overthrown trees, whilst those on either side remain unscathed."

207. **Ocean rich in animal life.**—Although the surface of the ocean is less rich in animal and vegetable forms than that of continents, yet when its depths are searched, perhaps no other portion of our planet presents such fullness of organic life. Charles Darwin, in the agreeable journal of his extensive voyages,

justly remarks, that our land forests do not harbour so many animals as the low wooded regions of the ocean, where the sea-weed rooted to shoals, or long branches of fuci detached by the force of the waves or currents, and swimming free, upborne by air-cells, unfold their delicate foliage. The application of the microscope still further increases our impression of the profusion of organic life which pervades the recesses of the ocean, since throughout its mass we find animal existence, and at depths exceeding the height of our loftiest mountain chains, the strata of water are alive with polygastric worms, cyclidiæ, and ophrydinæ. Here swarm countless hosts of minute luminiferous animals, mammalia, crustacea, peridinea, and ciliated nereides, which, when attracted to the surface by particular conditions of the weather, convert every wave into a crest of light. The abundance of these minute creatures, and of the animal matter supplied by their rapid decomposition, is such, that the sea water itself becomes a nutritious fluid to many of the larger inhabitants of the ocean.

208. **Moral impressions.**—If all this richness and variety of animal life, containing some highly organised and beautiful forms, is well fitted to afford not only an interesting study, but also a pleasing excitement to the fancy; the imagination is yet more deeply moved, by the impressions of the boundless and immeasurable which every sea voyage affords. He who awakened to the inward exercise of thought, delights to build up an inner world in his own spirit, fills the wide horizon of the open sea with the sublime image of the Infinite; his eye dwells especially on the distant sea line, where air and water join, and where stars rise and set in ever renewed alternations: in such contemplations there mingles as with all human joy, "a breath of sadness and of longing." *

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* Humbolt's Cosmos, pp. 299, 303.

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